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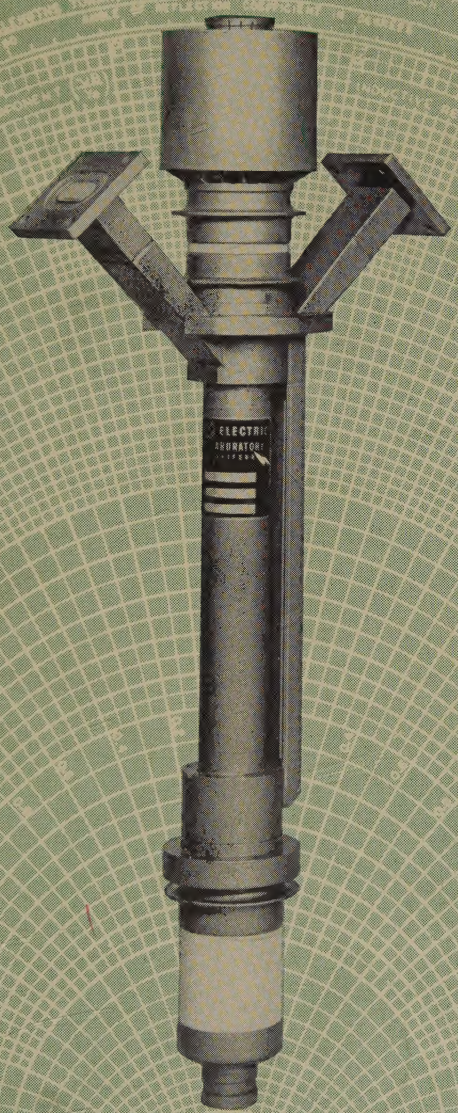
OL. 3 • NO. 1

- Straiton and Tolbert — Millimeters — The New Radio Frontier
- Houlding — Measurement of Varactor Quality
- Nalos — Present State of Art in High Power Traveling-Wave Tubes - Part II

he microwave journal



Dr. Bernard Herzog,
Philco Corp.
Govt. & Indus. Div.
3875 Fabian Way

Also In This Issue . . .

Report on International Conference for Waveguide Standardization

Solid State Circuits Conference Program

GAMMA-RAY
10^{20} CPS
10^{19} CPS
X-RAY
10^{18} CPS
10^{17} CPS
ULTRA-VIOLET
10^{16} CPS
10^{15} CPS
VISIBLE LIGHT
10^{14} CPS
INFRA-RED
10^{13} CPS
1,000 KMC
100 KMC
MICRO-WAVES
10,000 MC
1000 MC
TV
100 MC
COMM. AM-FM
10 MC
1000 KC
ULTRA-SONIC
100 KC
10 KC
AUDIO
1 KC
100 CPS
10 CPS
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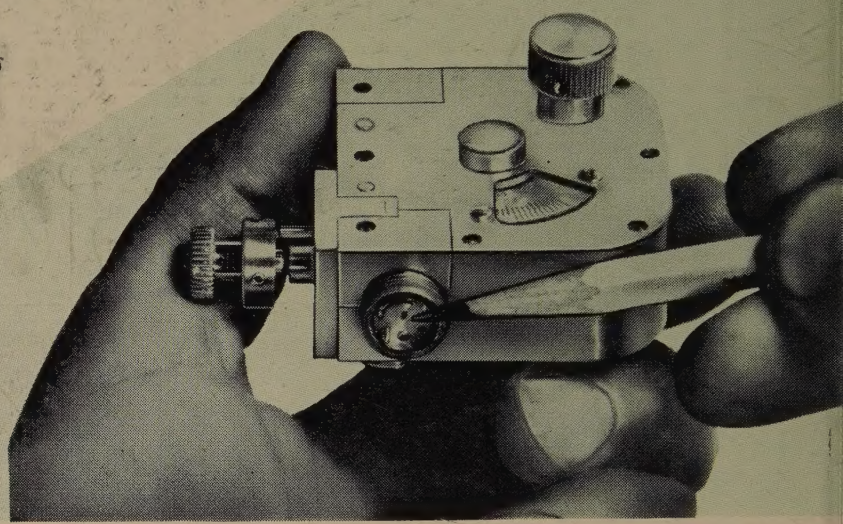
FREQUENCY

"...working in the 90-220 kmc frequency ranges?"

- *Crystal, Bolometer, and Thermistor Mounts.*
- *Harmonic Generators.*
- *Series, Shunt and Hybrid Tees.*
- *Slotted Sections.*
- *Precision Variable Attenuators.*
- *Standard Gain Horns.*
- *E/H Tuners.*

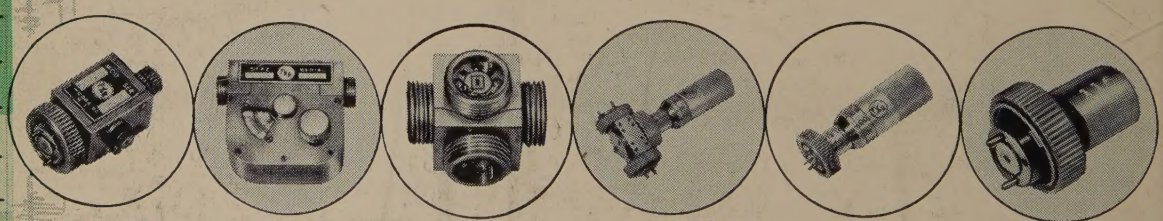
Other components shown below.

Slotted section, shown here, actual size.



FXR's Newly Developed and Proven 2-3 MM Components are Marvels *of Precision and Reliability*

These miniature F-Band and G-Band components are not scaled down versions of their lower frequency counterparts. Rather, they are instruments of individuality and precision — products of advanced microwave engineering and new manufacturing techniques.



DETECTOR MOUNT | PHASE SHIFTER | E/H TEE | FREQUENCY METER | ADJUSTABLE SHORT | TERMINATION

Brochure, including price list, available on request!

FXR, Inc.

Design · Manufacture · Development

Woodside 77, N. Y.

Precision Microwave Equipment · High-Power Modulators · Radar Components · Electronic Test Equipment

Radio Astronomy is the fundamental science which deals with the radio investigation of space. Each noise source provides its own contribution in the complex maze of microwave energy which surrounds us. A few decades ago, man added his own contribution in the form of communication transmitters, radars, and a vast host of radiators.

Radiometric systems calibrated directly in degrees Kelvin are the basic tools of a Radio Astronomer. A radiometer must be capable of sorting various noise sources available at its input and then amplifying the desired component.

Man-made receiving networks of the conventional variety introduce a considerable amount of internal noise, which is then further amplified. This noise is superimposed on the minute noise signals that are available at the antenna terminals; and hence the radiometer must not only select *noise from noise* at its input, but must identify the input noise signal in the presence of the normally high level of equipment noise.

Most cosmic noise signals are so weak that their total signal contribution represents only a small fraction of the noise power available at the radiometer output.

The state of the art recently established by Ewen Knight for the detection of broadband signals of noise-like character is .01°K, which represents a sorting of noise from noise from noise with an effective detectability 56 db below the total noise level.

Reprints of technical papers describing some of these techniques are available upon request.

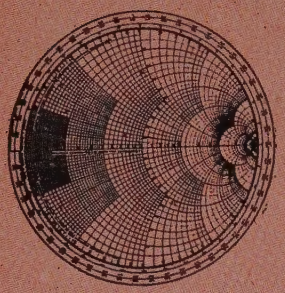
Personnel inquiries are welcome.

Ewen Knight CORPORATION

AT THE FRONTIERS OF *Electronics*

EAST NATICK, MASS.
Olympic 3-3300

JANUARY, '60 vol. 3 - no. 1



the microwave journal

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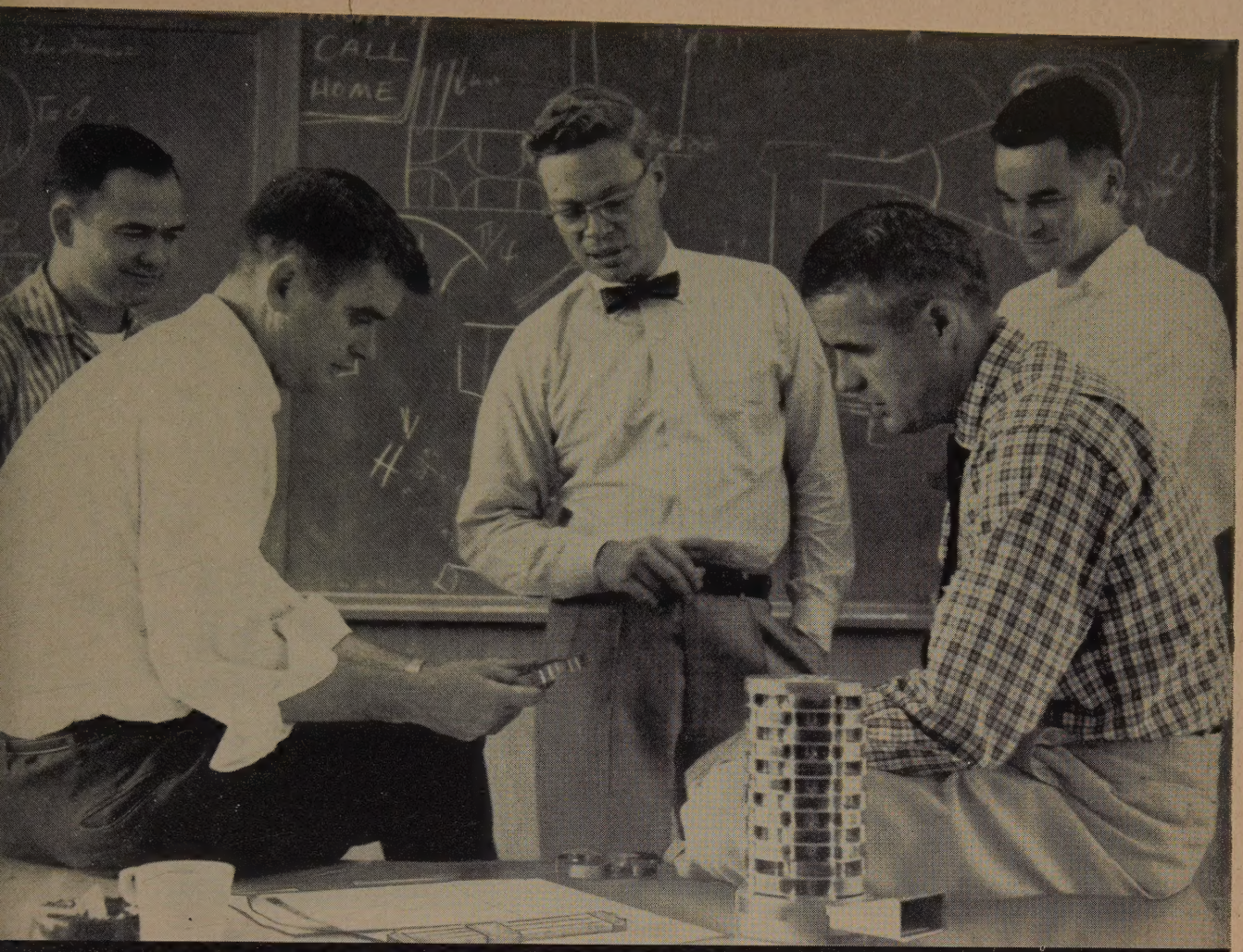

A few of Varian's large research team on wave tubes confer on new design features.

TOP TEAM IN WAVE TUBES

Varian has become the world's leader in the development and production of microwave tubes. With a greatly expanded wave tube team and larger manufacturing facilities, new tubes for advanced applications are being offered at an accelerated pace. From the small X-Band BWO's to the megawatt TWT, there is a Varian wave tube to meet your requirements.

Over 100 Varian Klystrons and Wave Tubes are pictured and described in our new catalog. Write for copy—address Tube Division.

VA-125A, B TWT	2.65 to 3.25 kMc 2 megawatts peak output
VA-161 BWO	8.2 to 12.4 kMc
VA-162 BWO	12.4 to 18.0 kMc
VA-128 TWT	2.6 to 3.4 kMc 10 kw peak output

VA-125A, B TWT

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VA-128 TWT

VA-161
VA-162
BWO's

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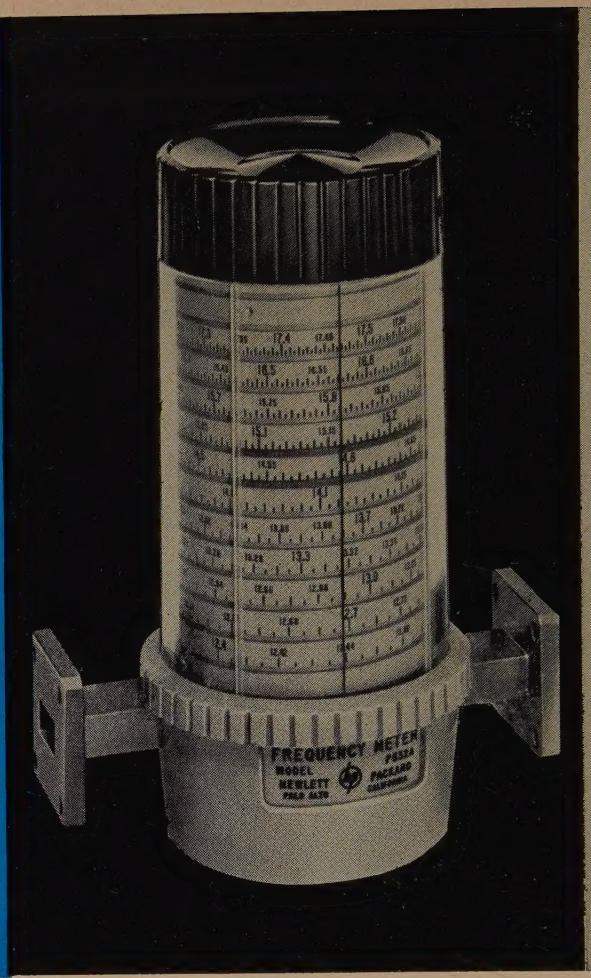
Wide band, direct reading, 0.1% accuracy FREQUENCY METERS 5.2 to 40 KMC!



NEW H, K AND R BAND MODELS

Now hp offers you high quality, moderately-priced precision Frequency Meters covering the important J, H, X, P, K and R microwave bands.

On models 532A (H through R band) frequency is read directly in KMC on the large, precisely-calibrated spiral scale. No charts or interpolation are required. Accuracy is high, typically 0.1%.

Model 532A Frequency Meters comprise a special waveguide section mounting a high Q resonant cavity tuned by a choke plunger. No sliding contacts are used, and the waveguide section transmits virtually full power at resonance. A dip in output indicates resonance. Tuning is by a precision lead screw, spring loaded to eliminate backlash. Scale lengths of 77" calibrated in 5 MC increments are typical.

For J band work (5.20 to 8.20 KMC) Model 530 Frequency Meters are offered (see Table). These instruments are similar to Model 532A except tuning is by a micrometer, and readings are converted to frequency by a chart on the instrument.

SPECIFICATIONS

Model	Accuracy	Frequency Range KMC	Fits Waveguide Size (in.)	Length (in.)	Price
J530A	0.1%	5.85 - 8.20	1½ x ¾	4	$120.00
J530B	0.1%	5.20 - 7.05	1½ x ¾	4	150.00
H532A	0.08%	7.05 - 10.0	1¼ x ⅝	6¼	195.00
X532A	0.08%	8.20 - 12.4	1 x ½	4½	150.00
P532A	0.1%	12.4 - 18.0	.702 x .391	4½	210.00
K532A	0.1%	18.0 - 26.5	½ x ¼	4½	230.00
R532A	0.2%	26.5 - 40.0	.360 x .220	4½	250.00

Other specifications: Models 532A: Resetability 0.01%, backlash 0.005%, SWR at resonance 1.3:1 approximately.

For complete details, call your hp representative or write direct.

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DEPT. 5491C 275 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.
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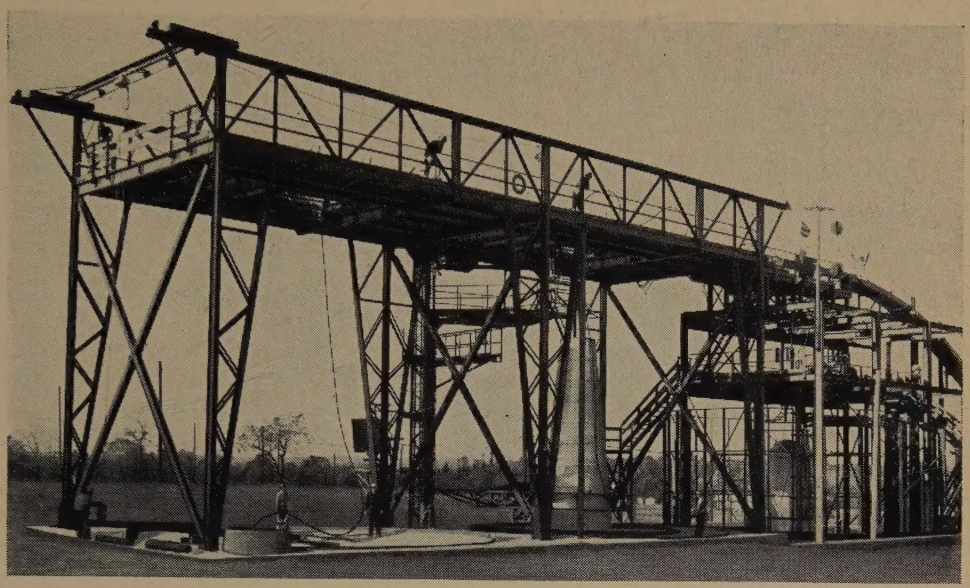
hp **complete instrumentation for microwave measurements**



SHIP WITHOUT AN OCEAN

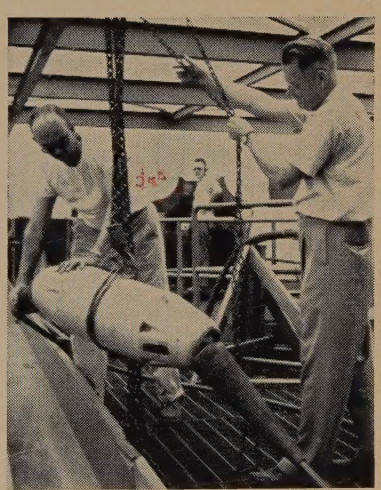
How do you lay a cable on the ocean floor—a cable that is connected to scores of large, heavy amplifiers? How do you "overboard" such a system in a continuous operation, without once halting the cable ship?

Bell Telephone Laboratories engineers must answer these questions in order to lay a new deep-sea telephone system designed to carry many more simultaneous conversations. They're experimenting on dry land because it is easier and more economical than on a ship. Ideas that couldn't even be attempted at sea are safely tested and evaluated.

In one experiment, they use a mock-up of the storage tank area of a cable ship (above). Here, they learn how amplifiers (see photo right), too rigid and heavy to be stored with the cable coils *below* decks, must be positioned *on* deck for trouble-free handling and overboarding.

Elsewhere in the Laboratories, engineers learn how best to grip the cable and control its speed, what happens as the cable with its amplifiers falls through the sea, and how fast it must be payed out to snugly fit the ocean floor. Oceanographic studies reveal the contours of the ocean bottom. Studies with naval architects show how the findings can be best put to work in actual cable ships.

This work is typical of the research and development effort that goes on at Bell Labs to bring you more and better communications services.



Experimental amplifier about to be "launched" from "cable ship." Like a giant string of beads, amplifiers and connecting cable must be overboarded without stopping the ship.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

MICROVIEWS OF THE MONTH

37 ▶ **MILLIMETERS — THE NEW RADIO FRONTIER**

Archie W. Straiton and Charles W. Tolbert

Characteristics of millimeter waves, wherein they differ from longer wavelengths, are discussed. Absorption effects by atmospheric gases, such as oxygen and water vapor, are examined, as are the advantages and disadvantages of the semi-optical nature of these extremely high frequencies.

40 ▶ **MEASUREMENT OF VARACTOR QUALITY**

Norman Houlding

A description and discussion of a technique for measuring varactor cutoff-frequency values are conservative and may be treated as lower limits, because cartridge and holder losses are included. The main features of the technique are: use of high frequency, exploitation of the variable capacitance property as an essential part of the measurement, and use of low-loss tuning elements to improve accuracy and simplify calculations.

46 ▶ **CURRENT STATE OF ART IN HIGH POWER TRAVELING-WAVE TUBES - PART II**

Ervin J. Nalos

The object of this paper is to outline the present state of art in the high power microwave field with special emphasis on linear beam circuits interacting with periodically loaded waveguides. A number of interaction circuits are discussed, both for "O" and "M" type tubes and areas of advances and future trends are indicated.

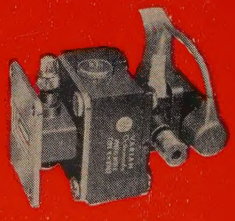
OUR COVER

General Electric's High Power Metal-Ceramic Traveling-Wave Amplifier. This tube, which was developed at the GE Microwave Laboratory, is designed for use in a pulsed high power amplifier chain. Featuring high gain, good efficiency and extended bandwidth, the tube is suitable for use in broadband coherent or frequency-diversity radar systems. See page 46.

V-8302 Orthomode*
Balanced Mixer

WORLD'S SMALLEST X-BAND BALANCED MIXER

Broadband and low noise without adjustment . . . only $\frac{1}{5}$th the size of conventional magic-T or short-slot hybrid mixers – $\frac{3}{4}$" x 1 $\frac{5}{8}$" x 1 $\frac{5}{8}$". Particularly suited to low noise missile and airborne radar applications where difficult packaging problems are encountered. Orthomode* Mixers are available at other frequencies. For detailed information, address Radiation Division.



V-8302 Mixer with Varian VA-217S Klystron and Bomac BL-S-504 crystal protector tube.

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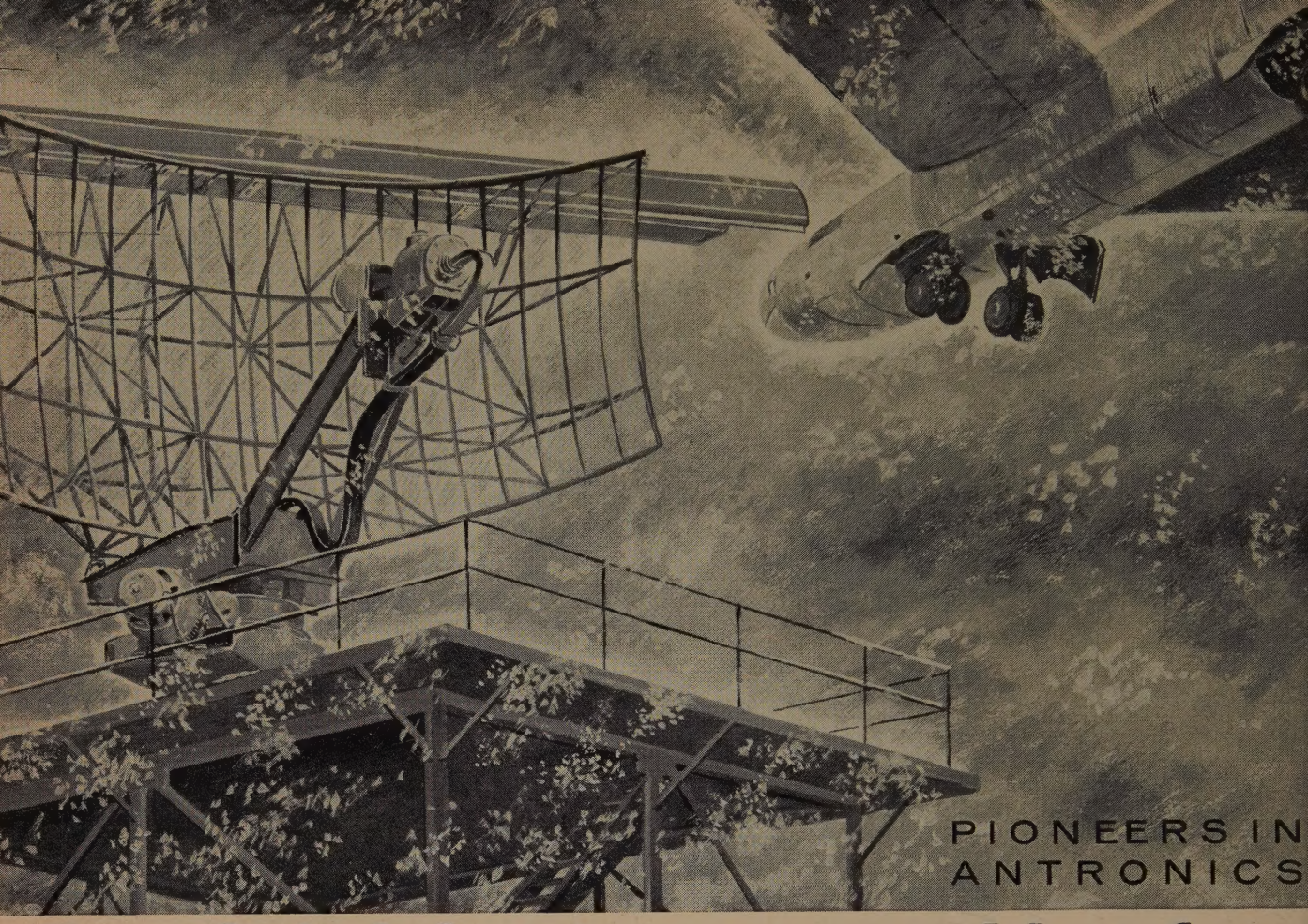
*TRADEMARK

Frequency range 8.5 to 9.6 kMc
Noise Figure at 9.2 kMc 9.0 db typical, including 3 db I.F. noise.
Signal Input VSWR < 2.0
I. F. Output Impedance —200Ω shunted by —10 $\mu\mu$f.
I. F. Frequency 20 to 120 mc.

KLYSTRONS, WAVE TUBES, GAS SWITCHING TUBES, MAGNETRONS, HIGH VACUUM EQUIPMENT, LINEAR ACCELERATORS, MICROWAVE SYSTEM COMPONENTS, NMR & EPR SPECTROMETERS, MAGNETS, MAGNETOMETERS, STALOS, POWER AMPLIFIERS, GRAPHIC RECORDERS, RESEARCH AND DEVELOPMENT SERVICES



Two Gabriel antennas combine for new dimensions in airport safety!

GABRIEL'S NEW ASR-4 ANTENNA, soon to be an integral part of the Texas Instruments ASR-4 airport surveillance radar systems in FAA Installations throughout the country, features high immunity to wind damage, plus remote-controlled linear and circular polarization. The major benefit of circular polarization is substantial reduction of the clutter effect of precipitation on the PPI, and a resulting boost to near range detection and control of aircraft.

ANTENNA ENGINEERS
Investigate new opportunities for employment at Gabriel. Expansion offers interesting positions. Call or write Charles Carlson, Director of Personnel.

GABRIEL'S NEWLY DEVELOPED ATCBI — a 28-foot, 32-cavity radiator STRIPLINE-fed beacon antenna — will soon be used in FAA Airport Traffic Control Systems in conjunction with ASR primary radars. When primary radar systems are supplemented by beacon equipment, air traffic control is measurably improved, identifying signals are stronger, moving and stationary targets are discriminated, and targets are not lost in scope clutter. The FAA Civil Beacon System will be effective even with the airport traffic densities anticipated for many of the larger cities.

Successful development of circular polarization and STRIPLINE techniques for systems such as the ASR-4 antenna and the ATCBI are bonus products of Gabriel's continuing program of advanced research in the design and performance of antenna components.

Circle Reader Service Card 6

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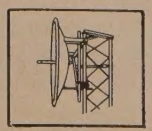
DIVISION OF THE GABRIEL CO., **MILLIS, MASS.**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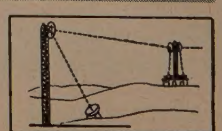
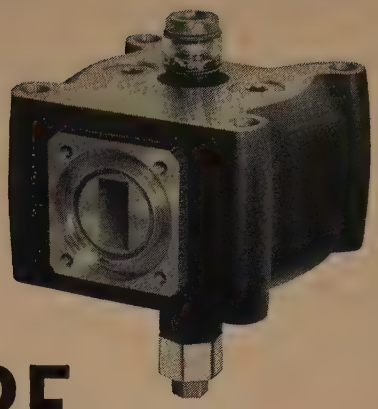

RESEARCH & DEVELOPMENT

TOUGH, TINY, TUNABLE TUBES MADE HERE



KU-BAND TUNABLE TUBES are the newest in a remarkable family of Litton Industries miniature pulse magnetrons. (There are more than 60 types of Litton miniature magnetrons. Production types!) The Ku-band tubes have power ratings up to 3 kw., minimum. Except for waveguide output, of course, they are mechanically interchangeable with companion X-band tubes available at power levels up to 4 kw., minimum.

We are reasonably certain that we spend more time making each tube than is the industry standard. We are also reasonably certain that we maintain the highest tube yield in the industry. A much larger numbe our magnetrons go to customers instead of to re bins. Implicit in this is tube reliability. Our extra in production has resulted in tubes that are perform well in excess of ratings. Since this means longer you can translate it into lower operating costs honest-to-gosh reliability for your systems.

Let us send you, without obligation, more informa on our wide line of electron tubes—evidence Capability That Can Change Your Planning. Li Industries, Electron Tube Division, Office M 960 Industrial Road, San Carlos, California.

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THE FEAR OF FAILURE

Throughout history one of the great obstacles to human activity has been the fear of failure. With increasing education and sophistication the fear of failure is becoming a more important control on human behavior.

Our present day society tends to worship at the altar of success. Failure is understood and condoned; yet many times a man afraid of failure is really afraid of social ostracism.

We do not believe that society is critical of an individual who has failed in honest endeavor. We do believe, however, that the fearing individual, himself, many times feels otherwise, and this fear of failing in the eyes of society is a strong motivating fact in his day to day actions.

It enters into the problem of making decisions. The fear of failure leads to procrastination and consequent inaction where action is called for.

With regard to assuming responsibility, the fear of failure tends to influence the individual against taking any responsibility, where responsibility helps a man to grow in stature.

The same fear of failure is leading to a decrease in the number of individuals capable of leadership.

The situation is unfortunate. However, there are still a few individuals who recognize this self-imposed limitation of his fellow man. They are the ones who are willing to make decisions, take responsibility and become leaders with due regard for the possibilities of failure but accepting their true significance.

A philosopher once said, "He only is exempt from failures who makes no effort." A study of the lives of some of the great people throughout history would reveal a startling high percentage of failures per individual. However, the failures and mistakes of a lifetime are the foundations of useful experience. Many times only through failures can the right direction be found.

We believe that it is important to convey to the young people of our day the necessity to face failure without fear, to rise above their mistakes and to be willing to risk criticism for the end results. In this way we will be able to help develop more and capable leaders.

This is still the land of opportunity for the individual who is not afraid of failure.

Ted Saad

HAVE TELECHROME

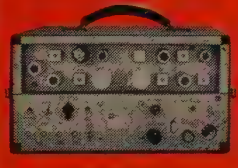
VIDEO TRANSMISSION TEST EQUIPMENT

WILL TRAVEL

IT'S PORTABLE

1003-C VIDEO TRANSMISSION TEST SIGNAL GENERATOR

Produces multi-frequency burst, stairstep, modulated stairstep, white window, composite sync. Variable duty cycle. Regulated power supply.



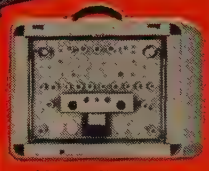
1004-B VIDEO TRANSMISSION TEST SIGNAL RECEIVER

Very rapid and accurate measurement of differential phase and differential gain characteristics of video facilities. Responds to standard stairstep test signal modulated with 3.58 mc, or any differential phase or gain test signal.

1005-A VIDEO TRANSMISSION TEST SET

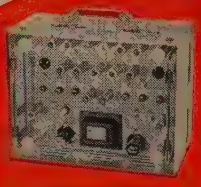
1005-A1 — Produces composite television waveforms suitable for measuring amplitude vs. frequency; differential gain vs. amplitude; dynamic linearity; differential phase vs. amplitude; high frequency transient response; low frequency transient response; low frequency phase of streaking, smears, mismatches; and other video characteristics.

1005-A2 — Supplies composite E1A Sync, blanking, horizontal and vertical drive signals and regulated B + power for itself and 1005-A1. Features magnetic core binary counters.



1008-A VERTICAL INTERVAL KEYER

Permits test and control signals to be transmitted simultaneously with program material, between frames of TV picture. Any test signal (multiburst, stairstep, color bar, etc.) may be added to the composite program signal. Test signals are always present for checking transmission conditions without impairing picture quality. The home viewer is not aware of their presence.



1073-CR SIN² SQUARED (SIN²) —SQUARE WAVE GENERATOR

Produces new waveform for testing TV or other pulse unit or system for amplitude and phase characteristics. Sin² — Square Wave pulse is equivalent to TV camera signal and is more sensitive than a Square Wave in indicating ringing. Video test signal adjustable for 1.0 volts or 1.4 volts peak to peak. Now in use by major TV networks and telephone companies.

Full Specifications & Details Available on Request

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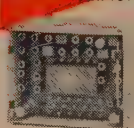
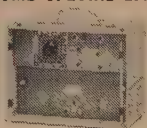
ALSO ASK ABOUT TELECHROME SPECIAL EFFECTS GENERATOR



Waveform Generator



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Switching Amplifier

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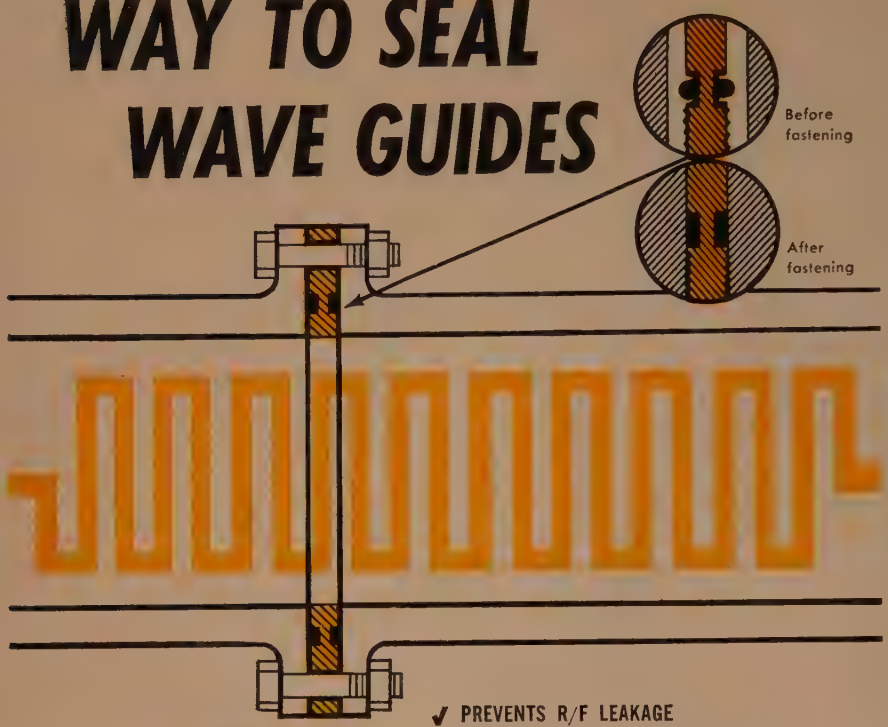
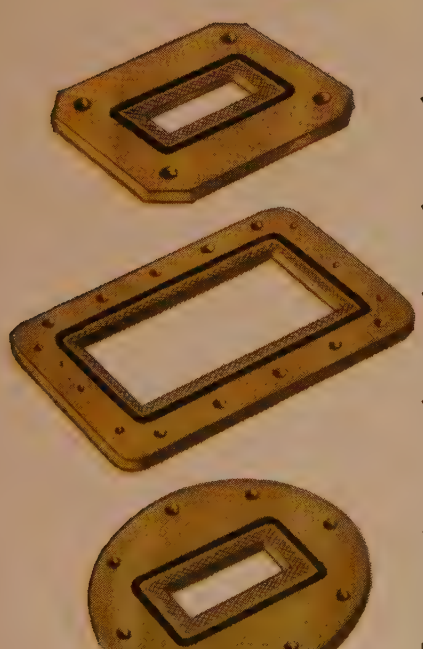
NOW THERE IS A BETTER WAY TO SEAL WAVE GUIDES





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Metal-to-metal contact with "engraved fingers" on inside surfaces assures electrical continuity.

✓ **PROVIDES NO-LEAKAGE SEALING**
Controlled confinement of seal gland assures safe, sure, positive sealing — **exceeds** top hermetic specs!

✓ **ELMINATES ARCING AND/OR BURNING**
Designed to exacting requirements for proper mating of flanges as specified.

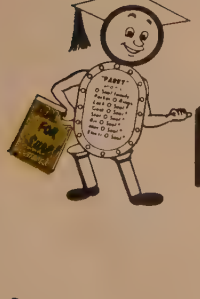
✓ **CAN BE RE-USED**
Seal is never "squeezed" beyond elastic limits, "memory" is constant, before, during and after fastening.

✓ **ECONOMICAL**
Eliminates cleaning or resurfacing flanges, no intricate machining required to accommodate the seal, and they're resuseable with just normal care.

✓ **STANDARDS FOR W/R SERIES**
Electr-O-Seals are available as standards to WR series Wave Guide flanges, assuring adequate supply and economy.

In addition to the standard WR series wave guide flange seals, Parker Seal Company also makes special seals to meet almost any specification or configuration. A nation wide group of field engineers are available to aid in expediting your requirements.

For more complete information send for catalog 5801.



Parker SEAL COMPANY
Culver City, California and Cleveland, Ohio
A DIVISION OF PARKER-HANNIFIN CORPORATION

Circle Reader Service Card 9

Letters

To the Editor

Editor

Dear Sir:

Several times recently I have come across references to degrees Kelvin used as a measure of microwave noise, both galactic and local in origin. I am suffering from a "learner weakness" — somewhere I missed the original derivation of this form of measurement.

Why is noise measured in degrees Kelvin? Does this pertain to amplitude of the noise signal only, or to frequency?

An advertisement of Ewen Knight appearing in your October issue says in part, "The state of the art recently established by Ewen Knight for the detection of broadband signals of noise-like character is .01°K, which represents a sorting of noise from noise from noise with an effective detectability 56 db below the total noise level." Granting that this is so, just what does it mean? That is, granting that 0 db equals 'total noise level' how many 'degrees Kelvin' would that be and why?

A stamped self-addressed envelope is enclosed.

Yours truly,
Paul A. Smith
North Chicago, Illinois

P.S. I have asked this question of six electronics engineers, five of them in the microwave field and have received six answers of "Gee, I dunno." I suspect that a great many of your readers do not understand many of the new terms which are appearing in the field. Maybe you should publish a short glossary of terms.

• *Mr. Smith's question was forwarded to Dr. H. I. "Doc" Ewen along with the stamped self-addressed envelope. Dr. Ewen's answer is reprinted for the benefit of the six electronic engineers and all other interested readers.*

Dear Mr. Smith:

Your letter of October 22nd to the Editor of *the microwave journal* has been forwarded to my attention for reply.

The use of thermodynamics terminology in the measurement of the noise characteristics of receivers is most common among radio astronomers and microwave engineers in the field of low noise amplification. I have enclosed a reprint from *the microwave journal* [March, 1959] which I feel will provide you with the background information which you requested. See in particular page 42, Section 2.0 "Some Radiometric Fundamentals."

In reviewing the advertisement which you noted in your letter, it occurred to me that there might be some confusion in connection with the .01° Kelvin sensitivity figure and the statement of "56 db below the noise level of the system," in view of the

(*Continued on page 14*)

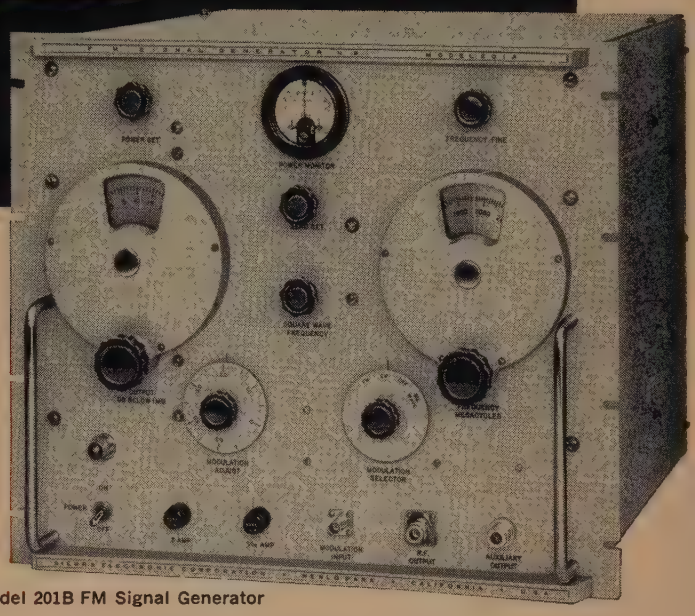
1300 to 2500 mc
FM SIGNAL GENERATOR

FAITHFULLY SIMULATES TRANSMITTER PERFORMANCE FOR SYSTEMS MEASUREMENTS

Superior FM characteristics, 1% deviation linearity. Precisely calibrated output continuously variable 0 dbm to —110 dbm. External modulation (to 500 kc) or CW output. Wide tuning range, vernier, direct reading.

Above are principal features of the new Sierra 201B UHF FM Signal Generator, specifically designed for telemetry and data transmission applications in the 1.3 to 2.5 kmc range.

Brief specifications here give more details; for full information and demonstration call your Sierra representative or write direct.



Sierra Model 201B FM Signal Generator

SPECIFICATIONS

Frequency	
Range:	1300 mc to 2500 mc in one band.
Tuning:	Separate vernier control for small changes in frequency.
Stability:	Drift not over 5 kc per minute.
Dial Accuracy	1%
R.F. Output—Calibrated	
Level:	Continuously variable 0 dbm to —110 dbm.
Output Accuracy:	Within ± 3 db from 0 dbm to —20 dbm, ± 1.5 db from —20 dbm to —60 dbm, ± 1 db from —60 dbm to —90 dbm and ± 3 db from —90 dbm to —110 dbm.
Source Impedance:	50 ohms, VSWR less than 1.6.
R.F. Output—Auxiliary	
Level:	Non-adjustable, 0 dbm to —5 dbm.
Isolation:	Exceeds 30 db.
Source Impedance:	50 ohms, VSWR less than 1.3.
Modulation	
Internal Squarewave AM:	100% AM modulated by internally generated 800-1200 cps squarewave.
External Frequency Modulation:	Deviation linear within 1% to 2 mc, within 2% to 3 mc. Response within 0 to —3 db, 100 cps to 500 kc.
CW:	CW signals have spurious FM hum and noise of less than 10 kc peak to peak.
AC Power Requirement	117 volts ± 10%, 50-60 cps, 200 watts.
Dimensions	Height: 15¾ in., Width: 19 in., Depth: 16 in.

sierra

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6096C BOHANNON DRIVE • DAvenport 6-2060 • MENLO PARK, CALIFORNIA, U. S. A.

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ssbm

RANTEC SINGLE SIDEBAND MODULATORS are microwave versions of techniques used for lower frequencies. Small, lightweight and rugged, they give far greater effectivity over traveling wave tube systems for doppler simulation. In addition, there are **ssbm** applications in radar ranging and in the generation of local oscillator signals.

Model	Freq. Range	Conversion Efficiency	Sideband Suppression	Carrier Suppression
MKU-200	12.7-14.5 kmc	15db	20db relative to desired sideband	20db relative to desired sideband
MX-201	9.6-10.6 kmc	20db	20db relative to desired sideband	20db relative to desired sideband

These specifications are typical when the modulators are used with Rantec drivers.

Rantec also manufactures a complete line of microwave ferrite components

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rantec corporation
calabasas, california

Circle Reader Service Card 11

Letters

(Continued from page 12)

fact that the noise level of the system was not specified. The equivalent noise temperature of the system described in the article was 4000° Kelvin, hence the noise figure was of the order of 11 db.

Sincerely,
H. I. Ewen,
President
Ewen Knight Corporation

— *m w j* —

Mr. Theodore Saad, *Technical Editor*
the microwave journal

Dear Sir:

Enclosed is a picture of a Backward Wave Parametric Amplifier for operation at S- to C-band signals by pumping at X-band. This amplifier can be electronically tuned by varying the pump frequency. The device is, in a sense, a microwave version of the low frequency prototype disclosed by Breitzer and Sard, in their paper published in the August issue of *the microwave journal.*

The backward wave parametric amplifier is analogous to the backward wave tube amplifier as was pointed out by Brietzer and Sard. The basic mechanism has been treated by Tien (*Journal of Applied Physics,* Vol. 29, No. 9, Page 1347-1357, September 1958 — see p. 1354). I would like to point out that there are two important differences between these backward wave parametric amplifiers and the backward wave tube. First, the nature of the backward waves is not the same. While the group velocities of the backward waves in both cases are along the backward direction, the phase velocity in the backward wave tube is along the forward direction, and that of the parametric amplifier is still along the backward direction. In the convention of tubes (see for example, Kleen — Electronics of Microwave Tubes, Academic Press, 1958, Page 259), the backward waves in the parametric amplifiers should be considered not as backward waves, but as forward waves propagating along the backward direction, i.e., backward traveling waves.

Second, in parametric amplifiers both the forward waves and the backward waves may have phase velocities equal to, or higher, than the the velocity of the light. In the case of tubes, the phase velocities are very much smaller than the velocity of light.

In the microwave parametric amplifier shown in the accompanying picture, the pump wave is supported by an X-band wave guide. The phase velocity is larger than the velocity of light.

Vary truly yours,
Hsiung Hsu
Electron Devices
Electronics Laboratory
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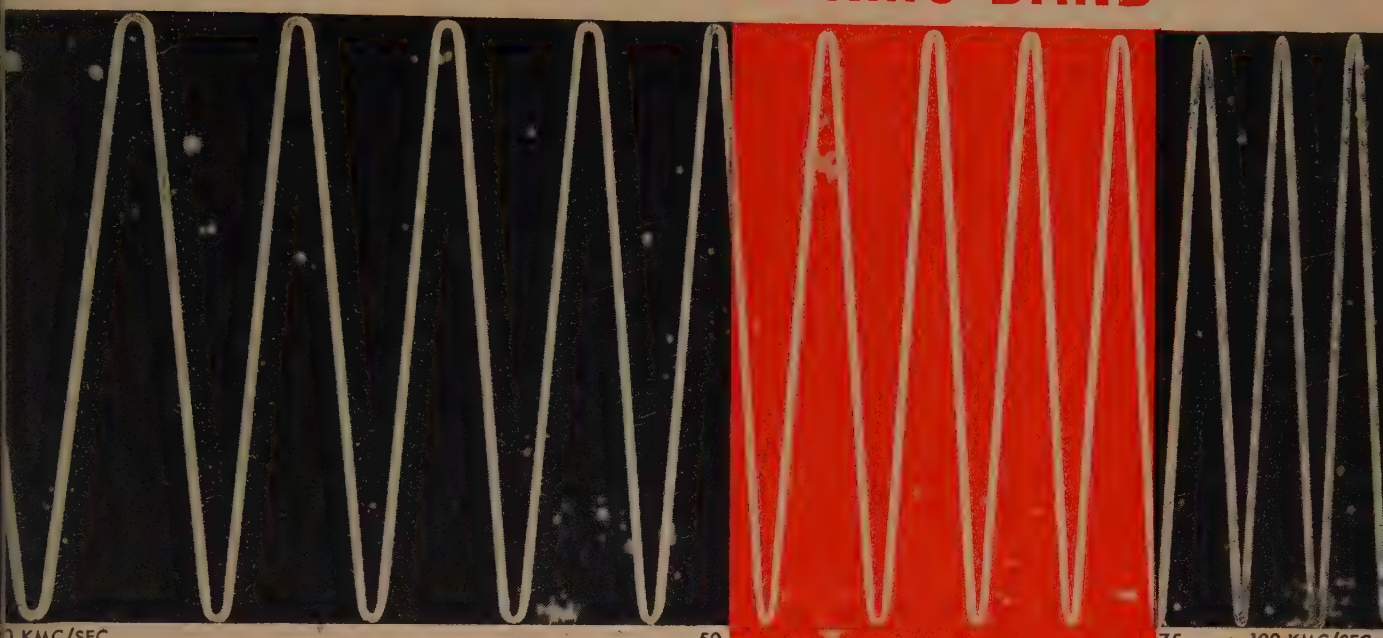
Now...PHILCO offers the only commercially available fully-tested mixer diode in the 70 KMC BAND



For Long-Range Space Communications and High Resolution Radar Applications

Just de-classified! A proven mixer diode that, for the first time, makes useful the 70 KMC high frequency band of the spectrum! Previously, the highest useful frequency was 35 KMC. The 1N2792 is a reversible crystal designed for optimum low-noise performance. The crystal is of integral waveguide construction with the diode mounted in a section of RG-98/U waveguide. It is hermetically sealed for resistance to moisture.

It is primarily designed for high resolution radar applications and for long-range high altitude or space communications . . . atmospheric absorption prevents jamming from the ground. The Philco 1N2792 is also well suited for EHF video detector applications.

Philco design and application facilities are at your disposal in developing millimeter diodes to meet your specific requirements. For complete information, write Special Components Dept. MJ 160.

Test Frequency.....69,750mc

	TYP.	MAX.	
Noise Ratio, NRo.....	2.0	2.5	times
Conversion Loss, Lc.....	8.4	10	db
RF Impedance, VSWR.....	1.35	2.0	times
Crystal noise figure, NF.....	11.5	13	db

PHILCO®

LANSDALE DIVISION, LANSDALE, PENNSYLVANIA

Circle Reader Service Card 12

NEW

THE MOST COMPACT LOW-PASS, HIGH-PASS MICROWAVE FILTERS

Available for Rated Characteristics

Frequency Standards now introduces a standard line of low-pass and high-pass microwave filters, the smallest and lightest available for rated characteristics.

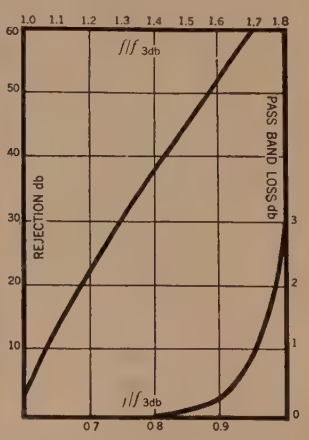
The filters can handle power capacities of up to 2 KW peak. All have a maximum insertion loss of 0.5 db in their pass-band. Input VSWR below the 0.1 db down point for low-pass filters and above it for high-pass filters is held to 1.5:1 or less.

Units are furnished with Type N RF connectors.

LOW-PASS FILTERS

Standard Low-Pass Filters Available

Model	1 db Down Frequency
FS 5L	500 MC
FS 12L	1200 MC
FS 23L	2300 MC
FS 31L	3100 MC
FS 60L	6000 MC

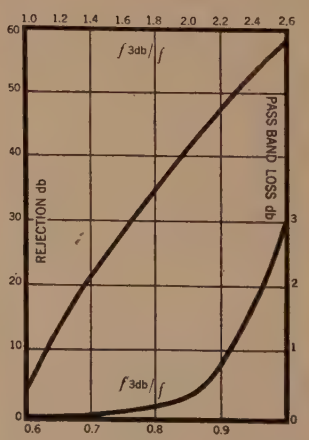


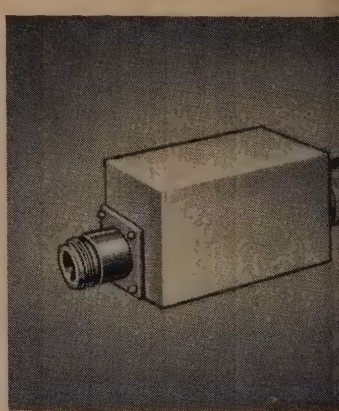
13 ELEMENT NETWORK

HIGH-PASS FILTERS

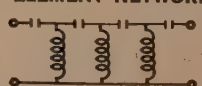
Standard High-Pass Filters Available

Model	1 db Down Frequency
FS 4H	400 MC
FS 9H	900 MC
FS 20H	2000 MC
FS 27H	2700 MC
FS 54H	5400 MC





7 ELEMENT NETWORK



Filters having other 1 db down frequencies, different numbers of elements or other types of RF connectors are available on special request

Write for Further Information

FREQUENCY STANDARDS

Division of Harvard Industries, Inc.

Box 504, Asbury Park, New Jersey

Phone: PRospect 4-0500 TWX A PK 588

GRIDDED MAS-1 SERIES 1KW S-BAND TWT's NOW AVAILABLE

Hughes Research & Development Laboratories, recognizing the requirement for a *gridded,* S-band traveling-wave amplifier, have developed the periodic, permanent-magnet focused MAS-1E tube. This advanced amplifier is ideally suited for use in today's and tomorrow's more sophisticated electronic systems.

Be sure you get and check the detailed specifications on this new Hughes *gridded* amplifier when your particular microwave application demands:

Periodically focused, pulsed-output power with a rise time in the low millimicrosecond range...high output power with low power input...minimum heat generation...light weight plus compactness...built-in reliability...immediate availability.

For detailed information *on the* MAS-1E *and other Hughes microwave products, write or wire:* HUGHES PRODUCTS, *Electron Tube Division, International Airport Station, Los Angeles 45, California.*

For export information, write: HUGHES INTERNATIONAL, *Culver City, California.*

CHARACTERISTICS
MAS-1E 1KW S-BAND TWT

Power output	1 kw peak, 10 w avg.
Power input	½ w (0.5 mw by cascading)
Frequency range	2.0-4.0 kMc
Saturation gain	33 db
Max. duty cycle	0.01
Beam voltage	7.0 kv
Grid control voltage	—90 v
Grid pulse voltage	+300 v
Weight (tube and magnet)	10 lbs.
Dimensions	15″ long, 3½″ o.d.
Grid capacitance	13 μμf
Environmental	Applicable Mil Specs

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NEW FROM NARDA

MICROWAVE MODULATOR

accepts over 40 magnetrons!

Here's the first of a series of new products from Narda's recently-established High Power Electronics Division! A high power Microwave Modulator that permits installation **inside the unit** of any of more than 40 magnetrons! Complete, compact and self-contained, it accepts magnetrons covering 3,200 mc to 35,000 mc, with peak outputs from 6 KW to 120 KW. Model 10001 features a completely interlocked circuit, with all high voltage leads and connections **internal,** for maximum safety; solid state high voltage bridge rectifiers for longer life and reduced heat output (prolonging life of other components, too); and built-in meters and viewing connectors for all principal parameters.

Other features are shown below. For complete specs and a list of at least 40 magnetrons suitable for use with the 10001, write Narda's High Power Electronics Division (HPED) at Dept. MJ-7.

SPECIFICATIONS

High voltage supply: Continuously variable from 0 to 4 KV at 100 ma; **Pulse power:** 18 KV at 20 amps max.; **Magnetron filament supply:** Cont. variable from 0 to 13 volts at 3 A; **Rep. rate generator range:** Cont. variable from 180 to 3000 pps; **Pulse width:** 1 microsecond at 70% points, rise time 0.15 microseconds, max. slope 5% (other pulse widths available); **Size:** 38" h, 22" w, 18" d. **Weight:** 150 lbs.

Complete 1959 catalog available on request.

the narda microwave corporation

HIGH POWER ELECTRONICS DIVISION

118-160 HERRICKS ROAD, MINEOLA, L. I., N. Y. • PIONEER 6-4650

Letters

(*Continued from page 14*)

The Editor
the microwave journal

Dear Sir:

In the article by Cohen and Steinmetz, "Amplitude and Phas sensing Monopulse System Parameters," published in *the micr wave journal,* volume 2, no. 10 of October 1959, there are sever points which may be of interest to readers. The authors should complimented on making a very complex subject susceptible easy understanding — they have no doubt achieved this objectiv

However, it may be well to realize that simplification also h its drawbacks. The data shown can only be used qualitatively a the qualitative values shown must be approached with reservation especially the values in graphs Figure 6 and 9, are liable to in error by large amounts.

The authors have used a sine wave for approximation for diffraction pattern. This is not the best known approximatio and this is serious when differences between two large numbe are studied — which is the case in the monopulse difference bea The best approximation for beam shape between 0 and — 10 is found to be $V = Ke$ raised to the $-c\theta^2$ power. Anoth slightly less representative approximation is $V = K\left(\frac{\sin c\theta}{c\theta}\right)$. Th authors would have been well advised to use the sinusoidal repr sentation for explanation and clarity, but to use the more accura and unwieldy approximations noted above for Figure 6 and 9 order to give the reader the best quantitative measures.

Studying the case of a 3 db cross over, we find the followi values normalized to e raised to the $-c\theta^2$ power value.

	e*	$\frac{\sin c\theta}{c\theta}$	cos $c\theta$
Slope of notch in difference pattern	1.0	1.1	1.2
Peak height for difference pattern	0 db	+ 2 db	+ 3 — 6 db**
Width of sum pattern at 3 db	1.0	.75	.65

*raised to the $-c\theta^2$ power

**depending on assumptions

Finally, the sinusoidal mathematics has an error. In equati (5) the "sin" term should be "tan," which causes a typical er of as much as 3 db in Figure 6, even based on the sinusoi assumption. Major shortening and simplification of the formul throughout, could have also been achieved by the following s stitution in the beginning.

$$\sin\left(\frac{\pi}{2} \pm A\right) = \cos A$$

Thank you.

Very truly yours,
F. J. Gardiner, Manager
Engineering Products Secti
Special Products Division
I-T-E Circuit Breaker Co.

• *Messrs. Cohen and Steinmetz made the following reply.*

The Editor
the microwave journal

Dear Sir:

We would like to comment on the critique made by Mr. F. Gardiner, ITE Circuit Breaker Company, in his letter to you da 23 November 1959. Mr. Gardiner suggests that equation (5) in error; that the function should be "tan" instead of a "si To resolve this matter a complete derivation of equation (5) presented:

Under paragraph titled "Phase Shift Effects," equal amplitu signals are assumed to exist in channels A and B for sign arriving on the boresight axis ($\theta = 0$). This signal level is sho to be equal to $\cos\left(\frac{\pi}{2}\frac{\eta}{\varepsilon}\right)$.

(*Continued on page 20*)

Greatest versatility!

• Highest accuracy!

• Widest range!

NARDA transistorized POWER METER

MODEL 440 ... **$250**

What's most important to you in a power meter? Accuracy? Portability? Independence from line voltage deviations? Wide range? Stability? Rapid warm-up?

Not that you have to make a choice...or a compromise any longer. The Narda Model 440 Power Meter gives you these features! Completely transistorized and powered by nickel-cadmium battery, rechargeable during operation or overnight, it offers two low-power scales in addition to the five standard scales (see below), a built-in charger with state-of-charge indicator and protection against overcharging, and freedom from internal heating caused by vacuum tubes.

Moreover, the 440 provides up to 18 ma bias current, enabling you to use the widest selection of bolometers and thermistors. In short, the 440 is the most versatile unit available to provide accurate direct-reading measurements of cw or pulsed-power automatically, over any frequency range for which there are bolometer or thermistor mounts. For complete data, contact your nearest Narda representative, or write us directly. Address: Dept. MJ-11.

SPECIFICATIONS

POWER RANGES: 7 SCALES

.01 mw full scale	—30 to —20dbm
.03 mw full scale	—25 to —15dbm
.1 mw full scale	—20 to —10dbm
.3 mw full scale	—15 to —5dbm
1.0 mw full scale	—10 to 0dbm
3.0 mw full scale	—5 to +5dbm
10 mw full scale	0 to +10dbm

.5 ma bolometers give best results on these scales.

Range Switch: 0.01 to 10 mw (full scale)

Accuracy: 3% of full scale reading

Bolometers & Thermistors: All 100 and 200 ohm, requiring up to 18 ma bias.

Battery Charger: Built-in; continuous or overnight. (Battery operable 16 hrs. before recharge required.)

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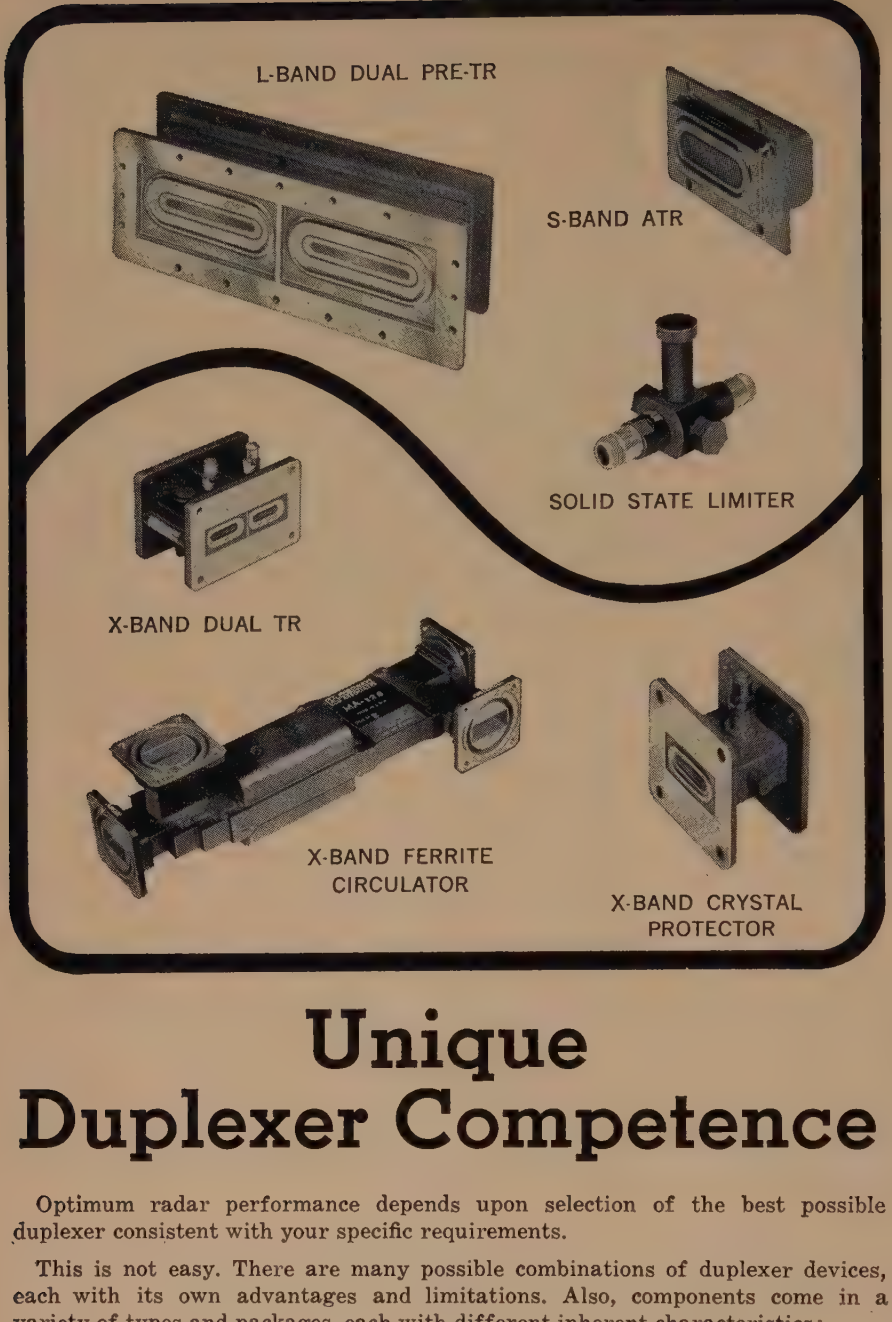

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Optimum radar performance depends upon selection of the best possible duplexer consistent with your specific requirements.

This is not easy. There are many possible combinations of duplexer devices, each with its own advantages and limitations. Also, components come in a variety of types and packages, each with different inherent characteristics:

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FOR SWITCHING & PROTECTION

- DUAL TR

Microwave Associates can help you select the correct duplexer for your system with no second-guessing. Their long-term research and development programs on gas tubes, ferrites, semiconductors, solid-state devices, and duplexer assemblies means excellence in duplexer capabilities. Production facilities are geared to rapidly translate new advances into field availability.

No other manufacturer offers you such comprehensive consultation on duplexer problems without obligation. If you are designing, building, or modifying a system we will be glad to work with you. Write or call:

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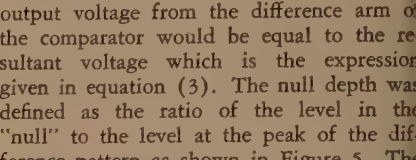
Burlington, Mass. • BRowning 2-3000 • TWX. Burlington, Mass. 942

Circle Reader Service Card 17

Letters

(*Continued from page 18*)

We can examine a system having a pre comparator phase shift, γ, by constructing the following vector diagram:



The diagram indicates that the "null" output voltage from the difference arm o the comparator would be equal to the re sultant voltage which is the expressio given in equation (3). The null depth wa defined as the ratio of the level in th "null" to the level at the peak of the dif ference pattern as shown in Figure 5. The paper points out that for beam separatio less than $\frac{\varepsilon}{2}$ the null depth changes be cause the peak amplitude is no longer unit but the value of the Lobe A pattern a Θ_{NB}.

Substituting $\Theta_{NB} = -\frac{1}{2}(\varepsilon\text{-}\psi)$ int equation (1), the expression for Lobe A, w obtain for the peak of the difference pat tern a value of $\sin\left(\frac{\pi\psi}{\varepsilon}\right)$. The nul depth ratio, in the domain $\bigcirc < \psi \leqslant \frac{\varepsilon}{2}$ is then

$$\frac{\sin\left(\frac{\pi\psi}{\varepsilon}\right)}{2\cos\left(\frac{\pi\psi}{2\varepsilon}\right)\sin\frac{\gamma}{2}} \cdot \text{ Letting } A = \frac{\pi\psi}{2\varepsilon}$$

and using the identity $\sin 2A = 2 \sin A \cos A$ we may rewrite the above expression a

$$\frac{2\sin A\cos A}{2\cos A\sin\frac{\gamma}{2}} = \frac{\sin\frac{\pi\psi}{2\varepsilon}}{\sin\frac{\gamma}{2}}.$$

Hence, the null depth in db is

$$20\log_{10}\left(\frac{\sin\frac{\pi\psi}{2\varepsilon}}{\sin\frac{\gamma}{2}}\right)$$ which is the sam expression as that shown in equation 5 Since Mr. Gardiner does not show an derivation, we are at a loss to see how h arrived at a "tan" function for this ex pression.

However, the major critique made b Mr. Gardiner concerns the advisability o using the sine wave approximation for th antenna patterns. Although he agrees tha the sine wave approximation is good for ex planation and clarity, he feels that som readers may use the quantitative results i Figures 6 and 9 without consideration fo the assumption made in their derivatio We would like to direct Mr. Gardiner attention to the paper's introduction.

There, we try to make it quite clear the reader that the major intent of th paper is to enhance the understanding the two systems and establish the manne in which various parameters affect syste performance. To present this informatio in the clearest form, we specifically te

e reader that we are going to make certain nplifying assumptions. Finally, in the st sentence of the introduction we caution e reader against doing what Mr. Gardiner ars, by saying, "Where the assumptions e not valid, the reader may make a sim- r analysis by substituting the appropriate dar characteristics."

Furthermore, the real value of these antitative figures, is that they tell a big rt of the system performance story at a ance. They give the operating engineer ll park numbers to work with and pro- de him with a "feel" for those parameters quiring particular attention. We are quite re that had the more accurate and un- ieldly approximation been used, we would ve arrived at the same general conclu- ons presented at the end of Part II.

In conclusion we would like to extend r thanks to Mr. Gardiner for his critique d his complimentary statement on the per achieving the objective of, "making a ry complex subject susceptible to easy derstanding." If this in fact is the inion of the majority of people reading e paper, then the paper has accomplished s mission.

Very truly yours,
William Cohen
C. M. Steinmetz
Stavid Engineering, Inc.

INDUSTRY NEWS

NEW ELECTRONICS FIRM FORMED

Announcement has been made of the rmation of a new electronics firm, An- nna Systems, Inc.

Officials of the company are: Charles . Creaser, Jr., President; W. W. Van- erWolk, Jr., Executive Vice-President; eon O. Paulding, Treasurer; Malcolm Vinsor, Chief Engineer; Russell Leish- an, Purchasing Agent, and Jordan routy, Staff Engineer.

These men were formerly with D. S. ennedy & Co., Cohasset, Mass.

The new company will be engaged ex- lusively in the design, manufacture and nstallation of complete antenna systems. new, high-precision, 30-foot parabolic ish is planned, with details to be an- ounced shortly.

Antenna Systems, Inc. will start opera- ions in January from the Hingham In- ustrial Center, Hingham, Mass.

Charles W. Creaser

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A major application is as a low-noise mixer diode following a low noise parametric amplifier in the 100 to 3000 mc range. Others include: UHF scatter, TV, telemetering, microwave links, radio navigation and astronomy, long range radar, and communications receivers.

COST REDUCTIONS
A significant cost reduction in UHF receiver RF front ends is possible by substituting this diode for the RF vacuum tube preamps, associated power supplies and other accessories previously required for low-noise figure performance.

HOW TO GET BEST RESULTS
In receivers designed for 1N21C or 1N21E diodes, maximum noise figure improvement is obtained by retuning RF match, adjusting local oscillator injection for lowest noise figure and the IF matching transformer for optimum IF impedance match of the 1N21F. For minimum receiver noise the 1N21F should be matched into a low noise IF preamplifier using WE 5842 triodes or similar tubes.

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DR. DEAN A. WATKINS

President, Watkins-Johnson Co.

•

Professor of Electrical Engineering, Stanford University

Creativity, versatility, productivity . . . each word seems equally important in describing the multiple talents of Dr. Dean Watkins. These talents have led him to success in a variety of occupations, any one of which would be a full time career for the average person.

For example, one of his current roles is president of the Watkins-Johnson Company, which he founded with Dr. H. R. Johnson in 1957. Now a thriving research and development firm in microwave electron devices, "W-J" employs 70 scientists, engineers, and skilled technicians, including a baker's dozen of Ph.D.'s. Its staff moved into a handsome new 13,000-square-foot research laboratory on the firm's 5-acre plot in the Stanford Industrial Park in August 1957, and an additional 24,000-square-foot facility for advanced development and production was finished early in 1959. Both Dean and vice-president Dick Johnson play active roles in the technical and administrative guidance of the company.

Meanwhile, Dean continues his regular duties as professor of electrical engineering at Stanford University. These include teaching a graduate course in electromagnetic theory, and guiding some half dozen graduate students on research projects under his supervision. The final portion of his course covers material on wave propagation and microwave circuits which he collected in an advanced graduate textbook, *Topics in Electromagnetic Theory,* published by Wiley in 1958. While at Stanford Dean also serves as director of Stanford's electron devices laboratory. This means he is responsible for the microwave solid-state and electron-tube portions of Stanford's multi-million dollar electronics research program. He shows no signs of overload under this busy schedule.

Watkins is a midwesterner by background, born in Nebraska in 1922 and educated at Iowa State. After college, he was an army engineer unit commander in both European and Pacific theaters of World War II. It was probably during this period that he formed the opinion that, "the French Riviera and the San Francisco bay region are two of the world's most habitable areas." While building prisoner-of-war stockades, roads, and bridges in England, France, Belgium, Germany, and on Okinawa, he commanded both negro and white troops, finding the negro soldiers intensely loyal and hardworking. The war period also saw his marriage to his college sweetheart, Bessie.

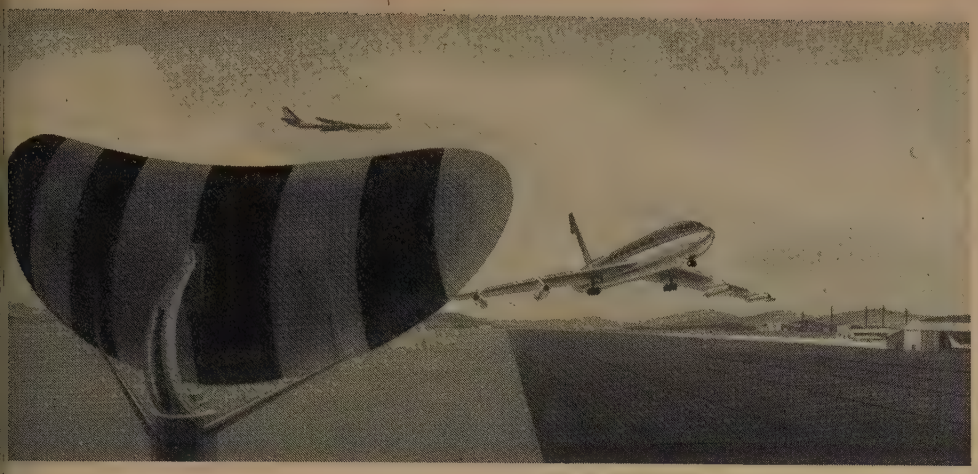
After the war, Dean received an M.S. degree from Ca Tech, worked for a year with the Collins Radio Company and spent another year on the technical staff at Los Alamos His career in microwave electron tubes did not begi until 1949, when he came to Stanford University as graduate student under Professor L. M. Field.

During his doctoral research, he invented the velocity jump principle of noise reduction in microwave tubes and thus made possible all the low-noise traveling-wave tube developments since then. His interest in low-nois devices remains strong today. After receiving the Ph.D in 1951, he joined the Hughes Aircraft Company, an within a year was promoted to head of the microwav electron tube laboratory. In 1953 he returned to Stanfor as associate professor of electrical engineering, and in 195 he received an appointment as one of the University' youngest full professors.

Watkin's twenty or so published research papers ten to be classics in their fields. At Hughes, his research i traveling-wave tubes and backward-wave oscillators led t a definite experimental study of the helix traveling-wave tube circuit. Since returning to Stanford, he has carrie

(*Continued on page 24*)

Dr. Watkins (right) discusses a problem with Dr. H. R. John son at his desk at the Watkins-Johnson Company.



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m price and delivery schedules are available for negative resistance, cavity type plifiers in the L, S, C, and Lower X-Bands. You can choose from either development dels for evaluation in your system, or custom designed, fully qualified units in production antities. The table at right shows typical amplifier characteristics now being obtained development models.

th noise figures as low as 2 db, these amplifiers are ideally suited to radar acquisition d tracking systems, tropo-scatter communications, telemetering, satellite tracking, and crowave relay links.

ey recover from overload in milliseconds—are resistant to deterioration and failure from gh power. Phase jitter and gain stability characteristics are excellent, and with the sociated ferrite circulator, the amplifier is fail-safe in case of pump or diode failure.

hall in size and weight, the amplifier can easily be retrofitted to many existing systems.

ghes Microwave Products can provide complete retrofit kits, including ferrite circulator, plifier, pump circuitry, and pump klystron, custom fitted to your system configuration.

HUGHES PARAMETRIC AMPLIFIERS—Typical Characteristics

	L Band	S Band	C Band	X Band
Pump	50 mw at S or C Band	100 mw at X Band	100 mw at X or K_u Band	150 mw at K_u Band
Gain	15 to 20 db	15 to 25 db	15 to 25 db	15 to 20 db
Bandwidth	2 to 10 mc	Up to 25 mc	Up to 25 mc	2 to 8 mc
Noise Figure	2 to 4 db	2 to 4 db	2 to 4 db	6 db
Remarks	Non-degenerate	Non-degenerate	Non-degenerate	Quasi-degenerate

For information on price and delivery dates, or for further technical data, write Microwave Products, Advanced Program Development, Hughes Aircraft Company, Culver City 2, Calif., or phone UPton 0-7111, Ext. 4727.

HUGHES

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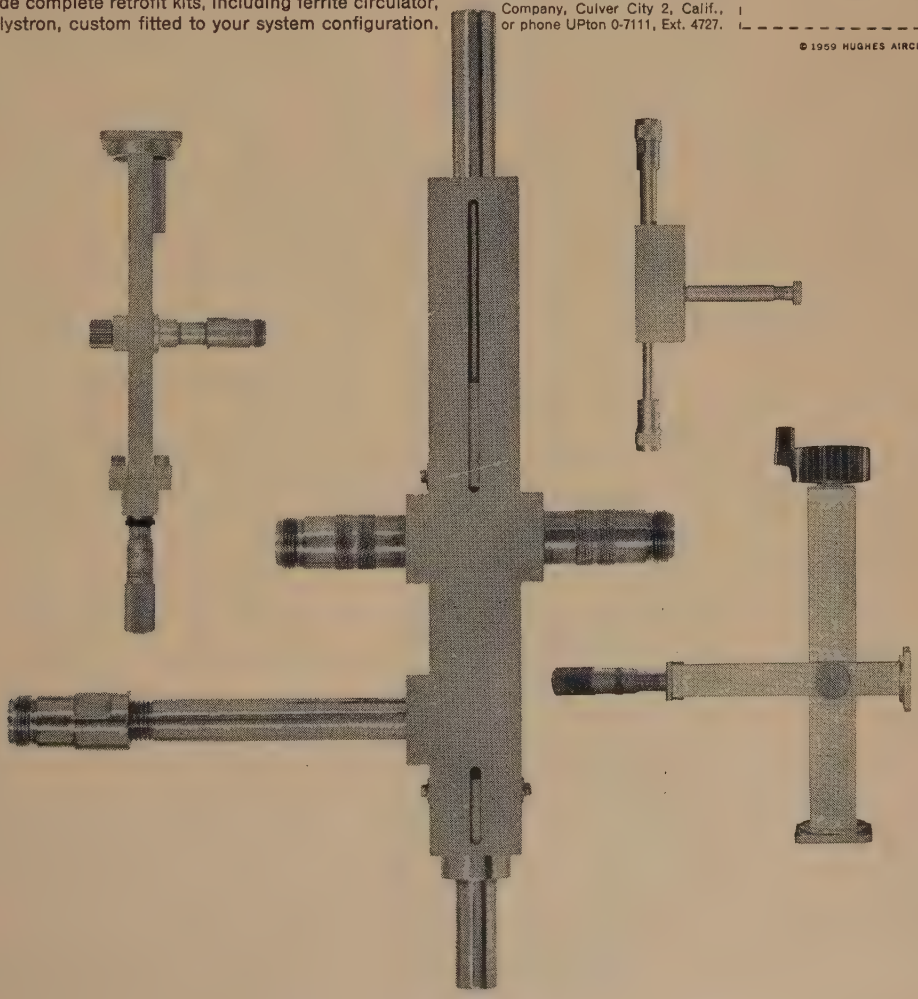

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(*Continued from page 22*)

on research in many areas. His interest in noise led him to propose and carry out with his students several basic analyses of noise in microwave diodes and microwave electron beams. One of these studies now appears to offer the correct theoretical explanation of recently observed noise figures well below the previously accepted theoretical minimum for traveling-wave tubes.

Another project under his guidance explored the possibilities of the transverse-field traveling-wave tube as a low-noise device. Still another byproduct of this research was an analysis of the effects of velocity spread on microwave tube performance. Watkins has published studies of backward-wave oscillator efficiency and large signal behavior, and at any early date constructed a helix backward-wave oscillator at a wavelength of 4mm. More recently he has found the long-sought explanation of a puzzling increase in BWO starting current at low voltages. Patents have been issued or are pending on six of his inventions, including the "helitron," a microwave oscillator tube which combines the voltage tuning of the backward-wave oscillator with the potential efficiency of the magnetron, and which requires no focusing magnet.

Dean believes strongly that major advances in systems performance ultimately depend on major advances in device technology, rather than on refinements of existing systems. He also finds research problems in engineering most satisfying when they are both challenging and of technological importance. With this in mind, he has attacked the problem of the heavy focusing magnet in a traveling-wave tube by carrying on studies of Harris-flow and electrostatic focusing for hollow electron beams. He has also developed a convergent-flow electron gun for crossed field tubes. Most recently he has proposed several novel ideas in such new fields as masers and parametric amplifiers, and he is currently directing research projects in the latter area.

His leadership in research and teaching have earned him the respect and loyalty of many associates. The dozen or more Ph.D. students he has guided during the past six years are to be found today in major industrial laboratories such as the Bell Telephone Labs, Hughes, IBM, Project Matterhorn, Zenith, and Litton Industries, and in faculty positions at Cal Tech and the University of Utah. Two of his students, Profs. Glen Wade and Tony Siegman, now teach at Stanford, while two others, Drs. George Wada and Boyd Israelsen, work with him at Watkins-Johnson. Other members of Watkins-Johnson who have previously worked with Watkins in various positions include Dick Johnson, who succeeded Watkins as tube laboratory head at Hughes; fabrication services manager Bruce Bleeker, who held a similar position at Stanford some years ago; engineer William Christensen, who assisted in developing the 4 mm BWO mentioned earlier; Dr. Les Roberts, a former graduate student; and last, but by no means least, his very capable secretary, Mrs. Louise Beer.

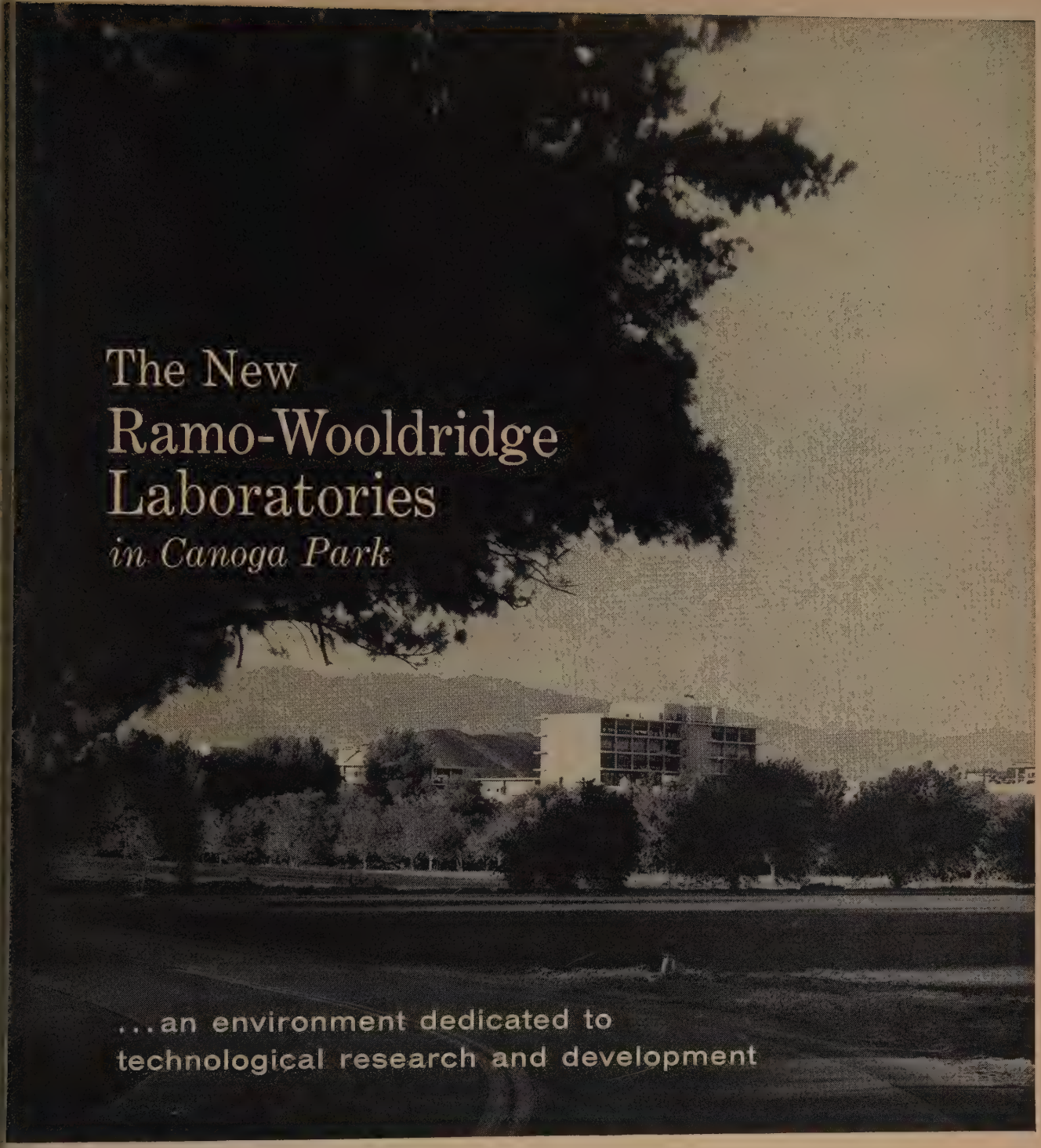
Professional honors awarded Watkins include the Electronics Achievement Award of the IRE 7th Region in 1957, and election as an IRE Fellow in 1958. He is a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu, and for several years has been a consultant member of the Defense Department's Advisory Group on Electron Tubes.

A special block in Dean's schedule is reserved for his three sons, who range in age from 6 to 11. Hiking with them in the foothills behind Stanford and near the family's attractive Portola Valley home is a favorite recreation. Poison oak is reported to be a major hazard in this hobby, however, and may well be the subject of a future research project. Another favorite recreation is selected reading, chosen from the history of America and the West, as well as from classical and current fiction. Current enthusiasms are Dickens' and Defoe's works, Russian novels, and *Lolita*. He is also a long-time sailing enthusiast, although he has been landlocked (no boat) for the past few years. He was recently elected a trustee of the local school board, and takes an active interest in community affairs.

Dean has given considerable thought to the factors which distinguish the productive from the unproductive research worker. In his opinion, strong motivation is as much if not more important than great mental ability. In his own case, it seems apparent that motivation, ability, and just plain energy must all be present in unusually large quantities. (One source of his energy may, of course, be the California sunshine. Dean, like many of the electrical engineering faculty, frequently spends his lunch hour in and around the Stanford men's pool.)

Watkins has also been interested in the theory that a researcher's major contributions are made during his twenties and early thirties. In his own case, the theory seems doomed to failure. If the present rate of activity is any indication, Dean Watkins' own career is still gaining momentum.

Dr. Watkins and Mr. Michel Beignot-Devalmont, one of his graduate students, are shown working on a plasma traveling-wave parametric amplifier project, at Stanford University.



The new Ramo-Wooldridge Laboratories in Canoga Park, California, will provide an excellent environment for scientists and engineers engaged in technological research and development. Because of the high degree of scientific and engineering effort involved in Ramo-Wooldridge programs, technically trained people are assigned a more dominant role in the management of the organization than is customary.

The ninety-acre landscaped site, with modern buildings grouped around a central mall, contributes to the academic environment necessary for creative work. The new Laboratories will be the West Coast headquarters of Thompson Ramo Wooldridge Inc. as well as house the Ramo-Wooldridge division of TRW.

The Ramo-Wooldridge Laboratories are engaged in the broad fields of electronic systems technology, computers, and data processing. Outstanding opportunities exist for scientists and engineers.

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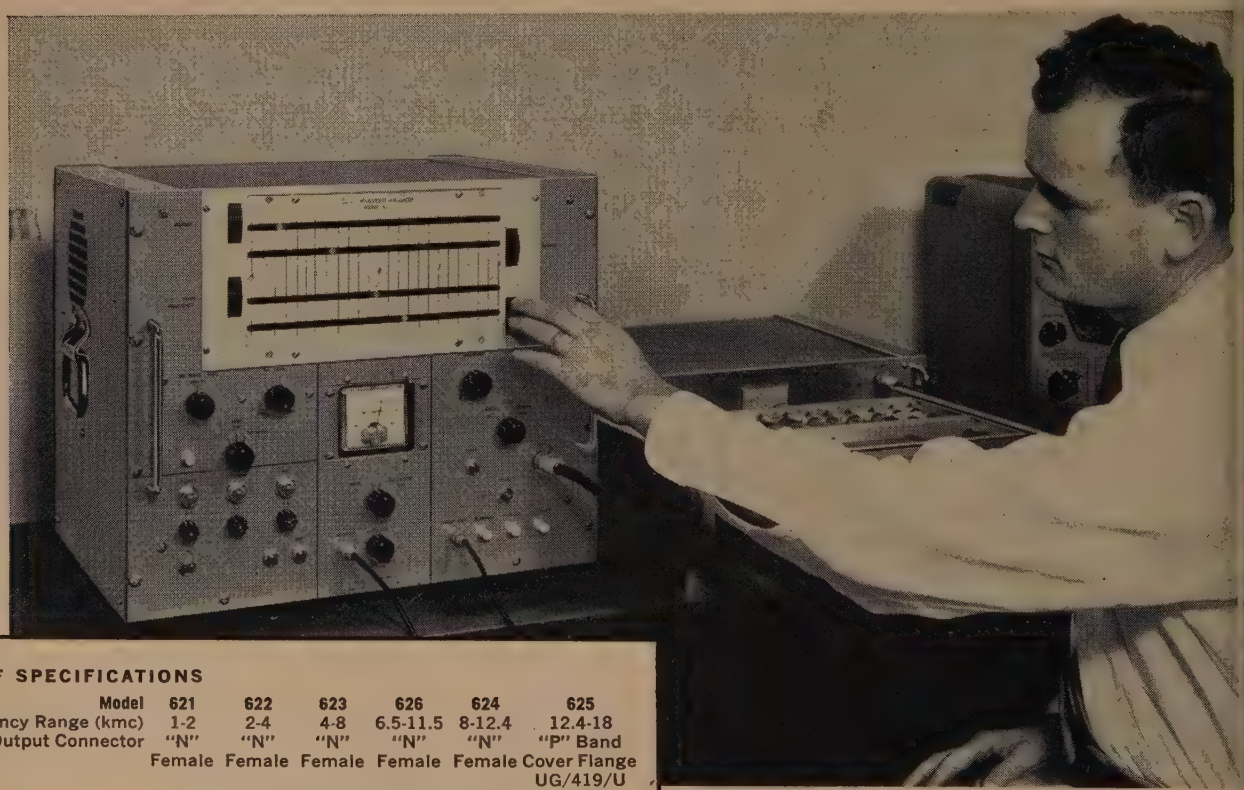

Using Alfred Model 623 Microwave Oscillator (left) to test small signal and saturation gain of Model 503 Traveling Wave Tube Amplifier. Microwave Leveler, Alfred Model 704, holds power output from oscillator constant within ±1 db.

BRIEF SPECIFICATIONS

Model	621	622	623	626	624	625
Frequency Range (kmc)	1-2	2-4	4-8	6.5-11.5	8-12.4	12.4-18
RF Output Connector	"N" Female	"N" Female	"N" Female	"N" Female	"N" Female	"P" Band Cover Flange UG/419/U
Prices	$3090	$2990	$2890	$2990	$2890	$3450

GENERAL

FREQUENCY CONTROL: Continuously adjustable with direct calibrated dial. Calibration accuracy, 1%.

POWER OUTPUT (minimum): 10 mw. Continuously adjustable from zero to maximum.

VSWR (maximum): 2:1.

SWEEP

SELECTOR: Recurrent sweep, single sweep, CW, and external on panel switch.

CONTROL: Single sweep, triggered by panel button, or external positive going signal 20 volts or greater.

SWEEP WIDTH: Continuously adjustable from 0 to any part of entire frequency range.

TIME: 100 to .01 seconds.

MONITOR OUTPUT: Positive linear sawtooth, 45 volts peak; Blanking out, 75 volts negative.

EXTERNAL SWEEP: 200 volts gives full sweep width.

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EXTERNAL: 30 volts maximum signal increases RF output from 0 to maximum.

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THE PROBLEM OF *Elegance*

MARSHALL PEASE

Sylvania Electric Products · Mountain View, California

ASSOCIATE EDITOR, *the microwave journal*

As a theoretical engineer, we are, on occasion, faced th the "problem of elegance." Having solved a prob- n with some weird new formalism that, in our pride invention, seems "elegant," should we then insist on s symbology, requiring that others take the trouble adjust themselves to it? Or should we translate it into nventional terms, reserving the new formalism for our n private enjoyment?

The problem is not confined to mathematical questions. exists, with various degrees of obviousness, throughout gineering. When is one justified in inventing a new cuit or component to do a job that can be done with isting designs? If a bent pin will hold a thing in place, hen should one bother to develop a proper jig? When, the face of a useable but sloppy solution, should we k for the elegant one? It is a problem that pervades gineering.

It is, however, in the mathematical questions that it comes most clear-cut. Here it is not obscured by ques- ns of expense or reliability. Here, too, there is rarely question of the useability of the standard techniques. is not likely that a new formalism will allow the solu- n of problems that are utterly insoluble by conven- nal means. If it does, it would involve the invention a new mathematics, and this the theoretical engineer is ely trying to do. Furthermore, it can be said that the w formalism will rarely much affect the actual labor of lculation. There is what B. Friedman has called the rinciple of the Conservation of Difficulty." Generally eaking you are faced with about the same number of ithmetic operations to get a numerical answer to a given estion, no matter how you arrange things. The only kely exceptions to this are when either the poorer ethod involves calculating the answers to a lot of other estions that are of no immediate interest, or when a od formulation of the problem allows you to lift bodily e calculations from some other problem. Otherwise, the nount of labor is rarely much affected by the formalism ed.

It is in this type of problem that the question of ele- nce arises in its purest form.

Having carried the thought so far, it might appear that ere is no virtue at all in elegance; that it carries no bene- ts at all except as an exhibition of ingenuity and for the nfusion of the uninitiated. It might appear to be only manifestation of the "witch-doctor" psychology that akes it pleasing to be able to pull an answer out of a ass of symbols that is incomprehensible to anyone not f the cult.

This, of course, is not true. In its proper place and properly used, the formalism does matter. On occasion, it matters a great deal. But it is true that it matters, not because of its effect on a specific calculation, but because of the insight it gives into a class of problems.

If a specific problem stands alone and unique, then it usually does not matter much what method we use to resolve it, subject, of course, to the limitation that our method must be both correct and finite. But the problems that arise in engineering are rarely unique. The specific problem is representative of a class, and the bigger that class, the more valuable is its solution.

We can, then, ask three questions. On their answers depends the value of a new formalism.

I: Does it give us greater insight or intuition into what can be calculated or proven? Does it, in other words, suggest to us what relations may be inherent in the physical problem whose existence we would otherwise not suspect? Such relations may be of great importance and not at all obvious. If we do not suspect their existence, then they will do us no good.

II: Does it suggest to us the manner in which such a calculation or proof can be undertaken? Does it give us ideas, right or wrong, as to how to proceed?

III: Finally, does it imply, or seem to imply, a wider area of application than we might otherwise suspect? Does it broaden the range of problems of which the specific

one is representative? That a problem is representative of another does us no good at all, if we do not see the connection.

It is not difficult to think of cases from the history of science and engineering that fit these questions. For the first one, we might cite the use of tensor formalism in General Relativity. Presumably, General Relativity could be enunciated without ever mentioning a tensor. After all, the tensor symbol is just a very abbreviated shorthand for a sequence of quite ordinary terms. Every equation of General Relativity can certainly be written without mentioning a tensor explicitly. But the likelihood that the theory might have been developed with an ordinary sort of formalism seems remote. The formulas would then be so incredibly involved as to make it improbable that anyone would even have started to look for the basic relations.

Or, again for the first question, we might consider the use of vector formalism in Electromagnetics. In this case, we know the problem can at least be stated in what was then the conventional formalism. Maxwell did. Vector analysis was introduced later. But certainly, the later introduction of vector analysis did much to help build the present state of knowledge in that field.

By distinction we may also cite the use of quaternions in that same field. There was, in fact, quite a fight between the proponents of quaternions and those of vectors, based on which was the most "natural." The historical decision was in favor of vectors. The eventual consensus was that vector analysis gave the more subtle insight into what could be done and that quaternions, while superficially attractive in being more like complex numbers, were, in the end, more difficult to work with.

For the second question, there is an interesting example in Heaviside's operational methods in transient analysis. It is interesting because of the reaction of the pure mathematicians. Heaviside argued that the techniques involved in his formalism should be regarded only as suggestions. If you wanted to be certain that the results were valid you could always check them by putting the answers back in the original equations. On this basis, it can be said that his formalism was specifically designed to give an affirmative answer to the second question. It did so in a way that was quite shocking to contemporary mathematicians who were concerned with rigor, not engineering usefulness.

This example is also interesting in that time has ruled so decisively in favor of Heaviside. What he did pragmatically has been justified by the mathematicians. They finally recognized its connection with the Laplace Transform, and extended the scope of the latter to include almost totally Heaviside's methods.

For the third question, we might, perhaps, cite the use of the Fourier Transform. Aside from its specific usefulness in various types of problems, it has also coalesced a tremendous range of problems into a single unity.

So, it is easy to find historical examples that fit these separate tests. Many more could be cited. Green's functions, the use of matrix notation, the wave concept and its generalization into the use of spectral representations, and so on until we have compiled a complete dictionary of useful analytic methods. It is only in situations that have not had the mellowing influence of age that it becomes a matter of fine judgment as to how those questions should be answered.

We may note as a general truism, which is at least as true as most truisms, that no new technique, at the time of its inception, fits any of the categories for anyone at all, with the possible exception of its author. This is true precisely because the method is new. We have our accepted ways of looking at things. We have a bibliography of problems that have been handled with the old methods. Faced with a new problem, we can probably find, in that bibliography, something that looks somewhat analogous. Perhaps falsely so. But even so, by the time we have figured out why it may be false — why the analogy breaks down in this particular case — we have then learned something about the present problem.

The new method, however, is brand new. We cannot use it until we have learned it. There must be an initial lag before it can be of any value to us in any way.

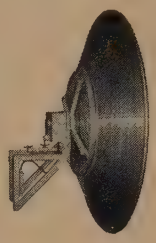
Furthermore, even after we have absorbed what its originator had to say about it, there is still almost no bibliography of problems solved with it. Each new problem tends to be completely new. Methods have to be worked out from scratch. The physical or other significance of formal relations in the new terminology must be laboriously studied as they arise. There is no past record on the basis of which we can assert that we automatically know the meaning of any results we get.

This can perhaps be illustrated best by imagining ourselves back when the issue of vectors versus quaternions for field description was in doubt. The virtue of quaternions was that they were an extension of the idea of complex numbers. Since engineers were used to complex numbers, the strain of adapting to quaternions did not seem too great. Vectors, on the other hand, were wholly new at least to most engineers. A statement that the curl of

(*Continued on page 30*)

Complete ANTENNA PATTERN INSTRUMENTATION

MODEL RANGE AND TRANSMITTING TOWERS



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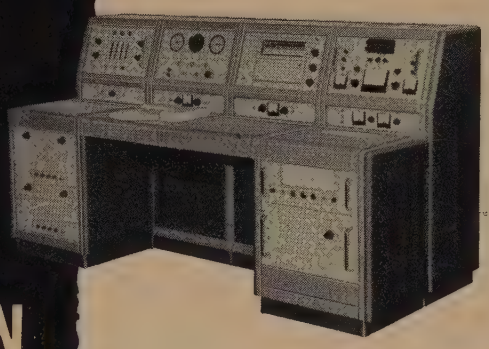

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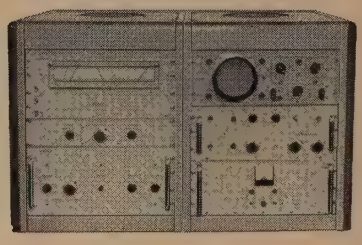

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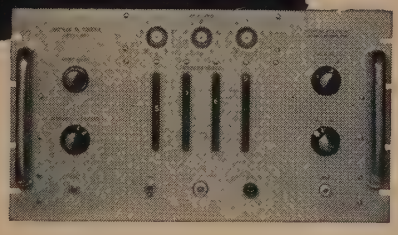

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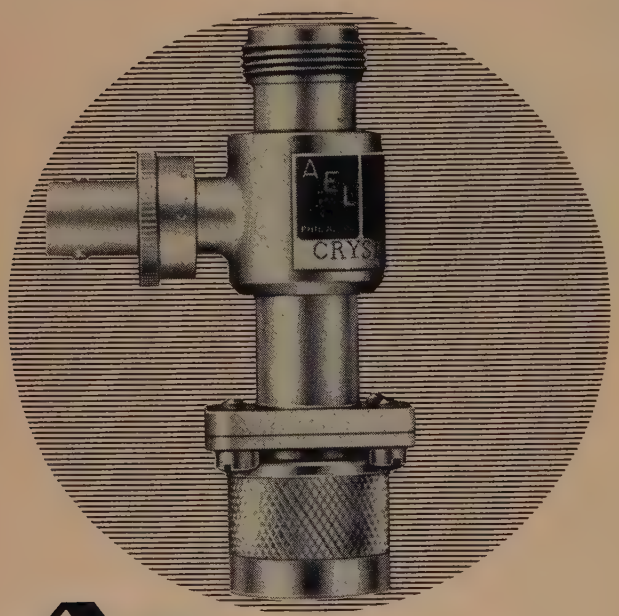

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Elegance

(*Continued from page 28*)

a vector vanished was meaningless to such people. This is not true now. Such a statement comes to us like an old friend. We feel, sometimes falsely, that we know what it means. And we are prepared to deal with it. But in the days we are speaking of, this was not so. Such a statement obviously had meaning. Any such uncomplicated form equalling zero is almost certain to be significant. And, in this case, it was clearly a tight restriction on the possible form of the field. Tight, but not determinative either. And to puzzle out just what kind of a field it could be under such a restriction required a lot of hard and creative work.

The astonishing thing is that people ever had the fortitude, the mulishness, or the idle curiosity to push the thing through to the point where it became a conventional tool of physics and of engineering.

That it did get pushed through was because there were people who pushed it through. People who hammered away on the logic, and on the physics, and on their colleagues, until finally it did come into its own.

Why? Almost every problem they tackled could be done by the conventional methods. So why did they bother?

The answer, perhaps, lies in this elusive label of "elegance." Elusive because it is not something that can be defined. It is an aesthetic property. A sense of unity, of fitness, of subtlety that says that the logic is intrinsic to the problem that it studies. A feeling of inevitability.

It is typical of the truly "elegant" solution that it takes a problem that we have, perhaps, been wrestling with for months; and solves it in a way that makes us wonder why it was ever confusing. We become almost ashamed to discuss our early struggles. They seem, in retrospect, so very unnecessary.

It is a quality that we have labeled as aesthetic, because it is a subjective one. It cannot be in the mathematics. The logic, after all, only says what it says. Mathematics is a very precise language, at least until you try to reach its philosophic basis. If x equals A, you know x precisely as well as you know A, neither more nor less. If a thing is proved, it is proven. Two proofs that start from the same postulates and reach the same conclusion are identical in total effective content. That one proof is more "elegant" than the other is a matter of psychology, not of mathematics. It is perhaps a statement that, following the one line of logic rather than the other, the mind is somehow able to grasp better the total logic of the situation in which the problem exists.

It is, we think, this subjective feeling of unity that is meant by "elegance."

We must, however, recognize a pitfall here. Since it is subjective, it is also personal. The approach that is elegant to one person, with his individual background of training and mental habit, may be sheer obscurantism to another. The use of a tensor formalism for the ordinary problems of field theory may be elegant to a physicist trained in relativity. To the engineer or the physicist specializing in the applications of electromagnetic theory, it is likely to be pointlessly confusing.

To the originator, and to those who may happen to match his general attitude and competences, it may be

(*Concluded on page 32*)

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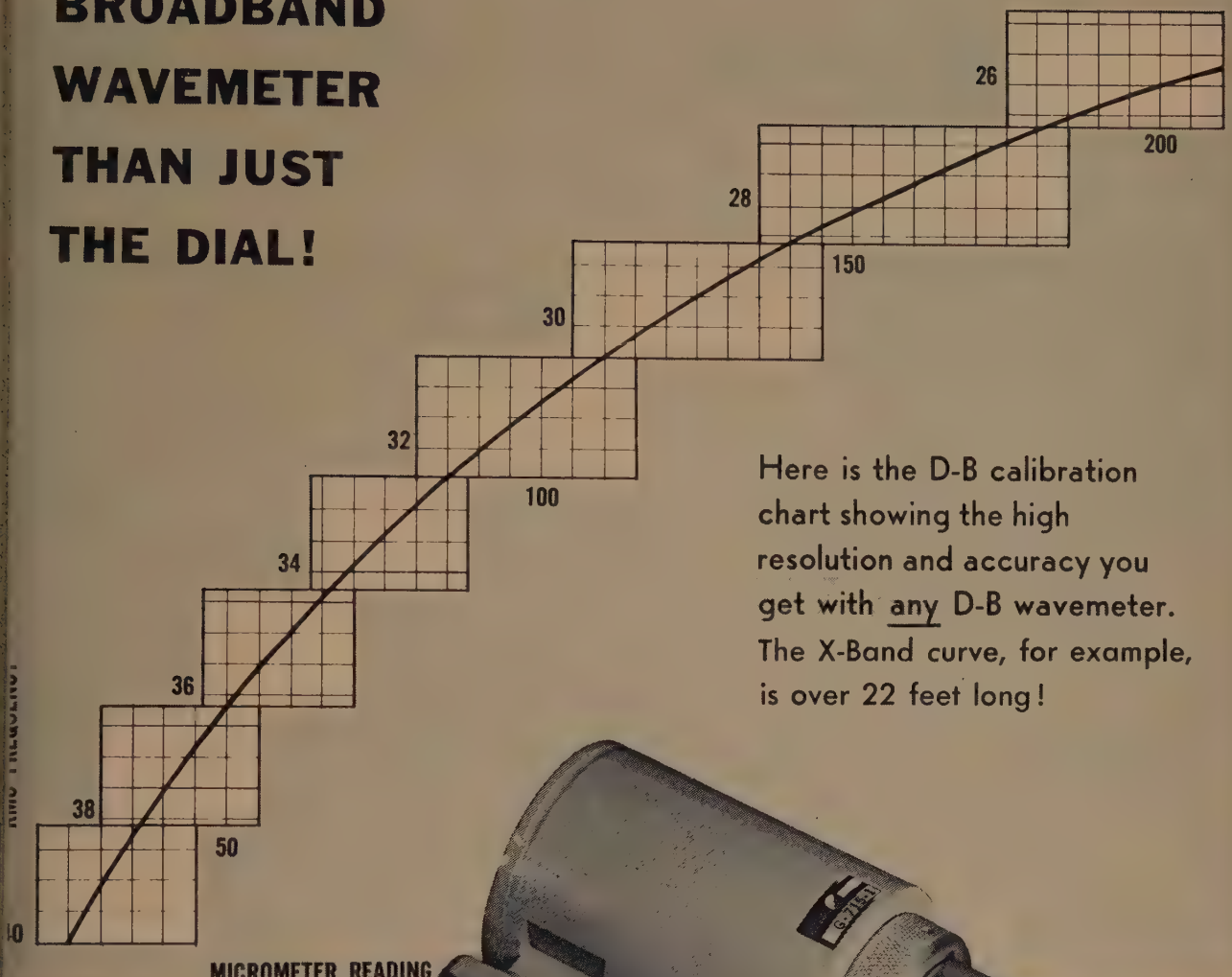

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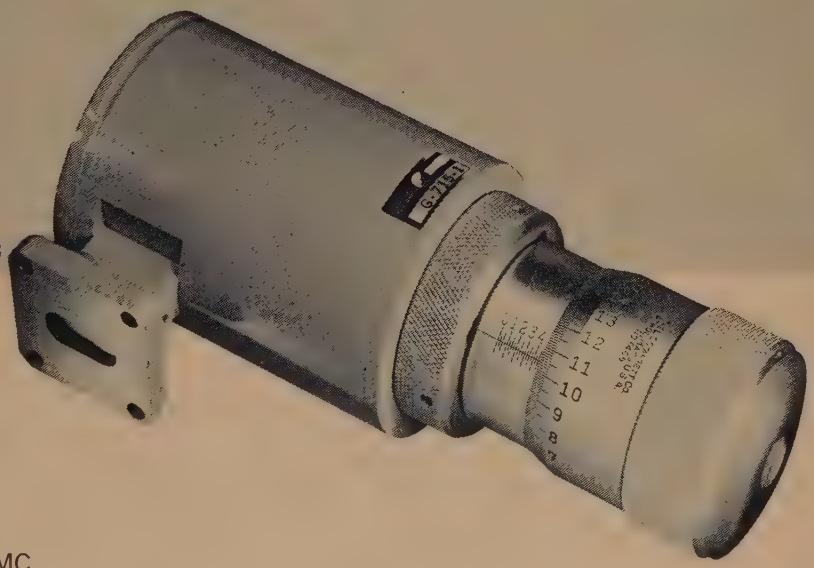

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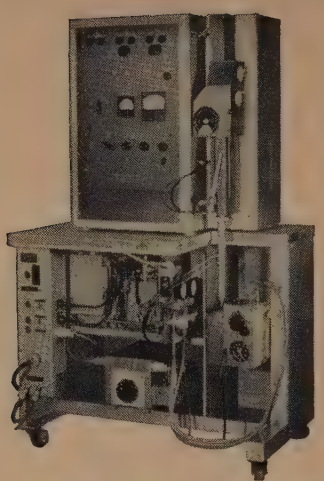

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(*Continued from page 30*)

truly elegant. To others, who, before they learn the new thing must first learn the background, the rewards may be slight for the work required. For the originator, the elegance may be true. For the others, it may be a down-right waste of time.

Finally, there is also the matter of false elegance. What the originator may deem to be elegant, at least from his own viewpoint, may not, in fact, be so at all. In the first place, if he has been wrestling hard with a problem when he finally does find a solution by whatever means he gets a glow of accomplishment. In the enthusiasm of this moment, it is easy to get carried away. If he does not later look at it hard, he may never see that the basic point was that he did not know well enough the conventional methods. Or, at least, that there was some point of the conventional method that he was overlooking. If, in other words, he takes the trouble to make the translation to conventional formalism, he may find that he ends up with a still better insight. That, even for him, the conventional approach is really the more elegant.

It is, therefore, very difficult to judge truly a matter of elegance. It is difficult in the works of others. It is even tough in one's own work. But a judgment is necessary. One must decide which formalism one should use himself, and which to use in public. The decision is not irrevocable, but it is unavoidable. It is a decision that requires the most objective type of deliberation. It is an engineering decision requiring the best that that term implies.

Although we have discussed the problem in terms of mathematical elegance from the viewpoint of the theoretical engineer, all that we have said is equally valid as we move across the spectrum to those who deal exclusively in "hardware." At the opposite extreme, we find those who must decide whether to make do with what is available, or whether to seek a new and more sophisticated solution. If the problem were unique and isolated, there would rarely be justification for any approach but the quickest "fix." But few problems are isolated. One looks ahead and sees the prospect and the opportunity of other problems of similar nature. Opportunity is involved because of the market that a new development may create or because of the need for continuous improvement of the job at hand. If the new approach is truly elegant, it will provide the leverage for that nebulous, but real opportunity. If the vision is false, if the new method turns out, for whatever reason, not to give the leverage that is needed, then the elegance is false. Whether it is true or false depends, not on the purely engineering aspects of the situation, but on a certain intuition as to what the situation will be and of what the approach may ultimately prove capable. The question must, again, be answered with an aesthetic sense of the unity between the idea and the problem. It is in this judgment that engineering becomes an art.

It is not, we think, too much to say that the problem of elegance is at the center of creative engineering. To the extent that it is solved properly and constructively and to that extent alone, does engineering become more than the technical application of specialized knowledge.

INDUSTRY NEWS

LOCKHEED TO FORM NEW SUBSIDIARY

Lockheed has announced plans to form new subsidiary, the Lockheed Electronics Company, as a further step in its program to extend its share of government and industrial markets for electronic systems, controls, and other devices.

The new corporation will include the recently acquired Stavid Engineering, Inc., and the Lockheed Electronics and Avionics Division (LEAD). These will be renamed the Stavid Division, in Plainfield, N.J., and the Newport Division, in Newport Beach, Calif.

Stavid, a military electronics engineering firm with 1,000 employees, specializes in airborne and shipboard radar, antisubmarine warfare research and development, fire control systems, missile guidance, field engineering, and simulation and automatic checkout equipment.

Lockheed last month began work on a 200-acre site at Newport Beach, Calif., for a modern electronics research and manufacturing center. This facility will serve as the headquarters for the Newport Division, which also will include the present LEAD plant in Los Angeles.

President of the Lockheed Electronics Company will be David F. Sanders, former Stavid president. M. Carl Haddon, Lockheed vice-president and LEAD general manager, will become a vice-president of LEC and general manager of its Newport Division. Frank J. Reynolds, Stavid executive vice-president, becomes vice-president of LEC and general manager of the Stavid Division.

— *mwj* —

POLARAD EXPANDS

Polarad Electronics Corp. has added 30,000 square feet to its Long Island City facilities to meet the growing demand for its line of industrial microwave instruments. This is announced by Dr. P. Lawrence Jaffe, president. The new space, located in a building adjacent to Polarad's present nucleus of three plants, is being leased from United Whelan Corp. It brings the Company's total plant area to about 70,000 square feet and will house all manufacturing operations for Polarad's industrial instrument line. Space formerly occupied by these operations will be absorbed by the Company's expanding research and development effort.

Polarad is a leading designer and manufacturer of microwave test instrumentation. It engages also in defense work involving counter measures, communication, navigation and missile ground control and test equipment.

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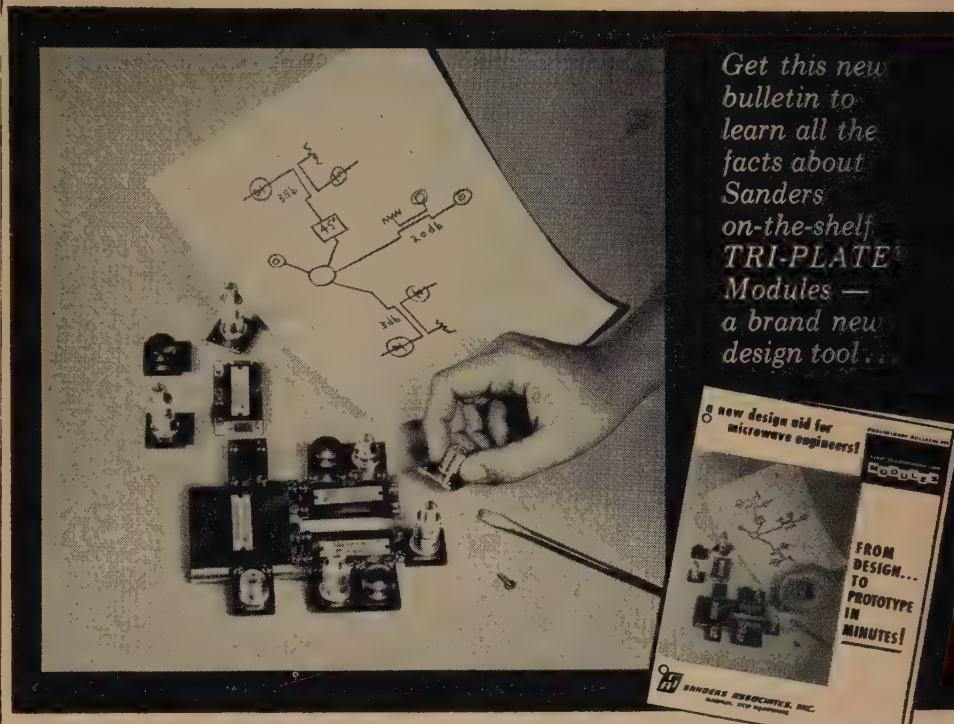
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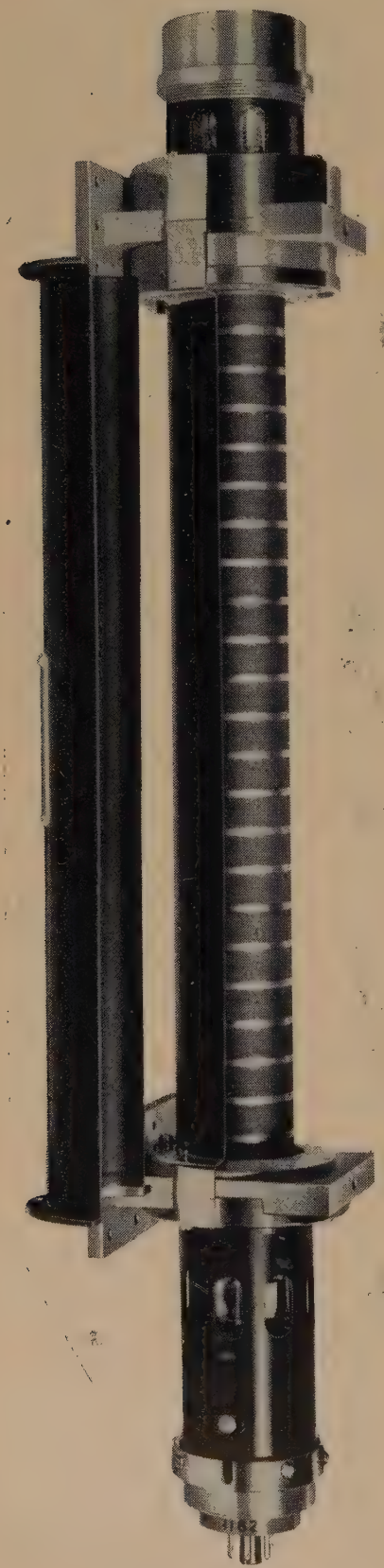
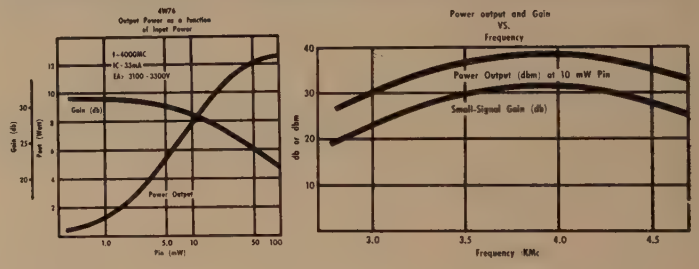


Production of traveling wave tubes at NEC began seven years ago and introduction of the package-type three years later. As chief supplier to Japan's complex network of microwave communications, NEC has become the world's largest maker of TW tubes. With the high development costs amortized and large manufacturing capacity, NEC is now able to supply these tubes at well below usual prices.

NEC's new doped nickel cathode core material, a 10-year development, increases both emission and tube life. It has been thoroughly field-proven in disc-sealed planar triodes for 2000-mc equipment of a large U.S. systems manufacturer (name on request). With its cooler operating temperature, evaporation rate of oxide is less than any other known core materials. This extends tube life up to 50%.

Designers will appreciate the compactness these tubes will give to their systems and operators the reliability and economy. Tubes connect to standard IEC waveguide flanges and can be shipped from stock. For specifications sheets, please write to Tokyo.



4W76

The 4W76 operates in the 4000-mc band and has nominal saturated power output of 10 watts. High amplification over a wide range of power levels results in small-signal gain of approx. 30 db. The band width at half-power points is 1400 mc, but the tube can be used in the frequency range of 2800 to 5000 mc.

Typical Operating Characteristics at 4000 mc

First Anode Voltage	2,640 V	Saturated Power Output	12.5 watts
Helix Voltage	3,220 V	Small-Signal Gain	32 db
Helix Current	0.7 mA	Noise Figure	approx. 25 db
Collector Current	33 mA	VSWR	less than 2 to 1 (from 3500 to 4300 mc)
Focusing Electrode Voltage	-40 V		

NEC TRAVELING-WAVE AMPLIFIERS

PERMANENT MAGNET FOCUSED AMPLIFIERS

4W75	4000-mc band	1.5 watts	8W75	7000-mc band	1.5 watts
4W76	" "	5-10 watts	8W76	" "	5-10 watts
6W50	6000-mc band	5-10 watts	11W17	11000-mc band	1.0 watt

ELECTROMAGNET FOCUSED AMPLIFIERS

4W85	4000-mc band	0.1 watt	4W72A	4000-mc band	1.5 watts
4W86	" "	1.0 watt	7W52	6000-mc band	5-10 watts

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NO focusing or impedance matching at installation
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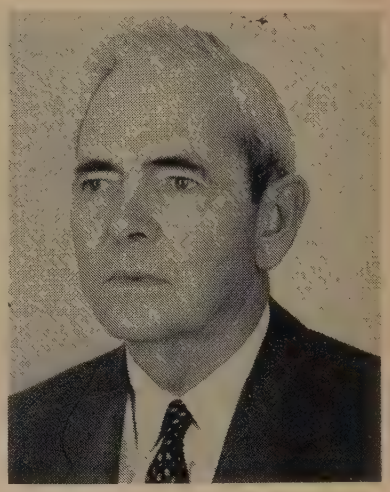
NEC *Nippon Electric Company Ltd.* Tokyo, Japan

COMPONENTS / SYSTEMS

CONTRIBUTORS IN THIS ISSUE

NORMAN HOULDING was born in England in 1917 and graduated from Manchester University in 1938. After industrial experience, he joined TRE (later RRE) in 1942. There he was engaged in research on radar receivers and allied problems, and was foremost in development of low-noise microwave receivers. In 1956, he joined Canadian Westinghouse in Hamilton, Ontario where he became Manager of Advanced Engineering section. In 1958, he joined Microwave Associates as Director of Varactor Research and has recently joined National Company, Inc. of Malden. Mr. Houlding is a Senior Member of the IRE.



ARCHIE W. STRAITON was born in Arlington, Texas on August 27, 1907. He received the degrees of B.S. in E.E., M.A. and Ph.D. from The University of Texas. He taught at Texas College of Arts and Industries from 1931 to 1943 and at The University of Texas from 1943 to the present where he is now Professor of Electrical Engineering and Director of the Electrical Engineering Research Laboratory.

Dr. Straiton is a member of Eta Kappa Nu, Tau Beta Pi, Sigma Xi and American Society for Engineering Education. He is a Fellow in the Institute of Radio Engineers and served as a Director in 1953-54. He was a former member of U.S.A. National Committee and Chairman of Commission II of the International Scientific Radio Union.

CHARLES WALTER TOLBERT was born in Homer, Louisiana on 28 August 1920 and attended public school in Beeville, Texas. He received the degree of B.S. in General Engineering from Texas College of Arts and Industries in June 1943.

For two years he was employed by the National Geophysical Company, before coming to The University of Texas as an instructor in 1945. Shortly afterwards, he joined the staff of the Electrical Engineering Research Laboratory where he has been responsible for much of the experimental program of the Laboratory.

In recent years, Mr. Tolbert has been in charge of the millimeter studies at The University of Texas and he has numerous publications in this field.

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MILLIMETERS — THE NEW RADIO FRONTIER

Archie W. Straiton
Charles W. Tolbert

ELECTRICAL ENGINEERING RESEARCH LABORATORY
UNIVERSITY OF TEXAS, AUSTIN, TEXAS

troduction

One of the scarcest commodities this country today is space in the dio spectrum. The increasing requirement for broadcasting services, blic and private communications, craft guidance, military applications d a thousand other uses of the radio ectrum has created a demand for ailable frequencies that far exceeds e supply.

This overpopulation of the radio ectrum has caused many to look ward the new frontier as an area for pansion of the useful radio spectum. The part of the spectrum, own as extremely high frequencies EHF), forms such a frontier. Its unds are from one millimeter wavegth to one centimeter wavelength ith corresponding frequencies of 0,000 megacycles per second and 0,000 megacycles per second. This equency range of 270,000 megacles is nine times that of all the her bands combined. It is no wonr, then, that millimeter radio waves e being investigated more and more equently for their application potntial.

Millimeter radio waves, however, not present a panacea for all of the dio requirements, but they, like ost frontiers, have their hardships hich may be quite discouraging to e explorer. It is the purpose of this paper to describe the unique characteristics of millimeter radio waves with the hope that it will be useful in evaluating their adaptation for specific purposes.

The two features of millimeter radio waves which separate them from their longer wavelength cousins are that they are in a frequency region where they suffer absorption by atmospheric gases and that their very short wavelength makes them have many of the characteristics of light waves. A successful use of EHF will be one for which these characteristics will be an advantage or one for which they will present little disadvantage.

Absorption of radio waves by the gases in the atmosphere is almost nonexistent for wavelengths longer than a few centimeters. Furthermore, optical wavelengths are also essentially free of this loss factor. The short centimeter, the millimeter and the infrared frequencies are, however, subject to this loss which may be very minor at certain frequencies and very severe at others.

The absorption by atmospheric gases results from the fact that radio waves cause changes in rotational energy levels of the molecules. Each energy level change has a particular frequency associated with it and this frequency is directly proportional to the change in energy involved. The absorption frequencies in the millimeter domain correspond to changes between levels with nearly equal energy content. At very low pressures, the absorption is associated with a very narrow region of the spectrum around this resonant frequency. For higher pressures such as that at sea level, the absorption occurs over a wide frequency spread. This broadening of the absorption lines is due to collisions between the molecules preventing free interchange of energy between the electromagnetic wave and the individual molecules. Thus, to evaluate the extent of the absorption it is necessary not only to know how much of the absorbing gases is present but also to know the total gas pressure. A particular frequency which may be very rapidly absorbed on a short path over the ocean, may be relatively free of attenuation between mountain peaks.

The absorption of millimeter waves is due primarily to two constituents of the atmosphere. These are oxygen and water vapor. The first of these is considerably simpler to treat because its amount is practically constant for a given altitude and because the pattern of the absorbing frequencies is relatively simple.

The interaction of the oxygen molecular and electromagnetic field results from the fact that the oxygen molecule has a magnetic dipole which

tries to align itself with the varying field. If the rotational frequency is nearly that of the incoming wave the energy transition will be accomplished.

The water vapor molecule on the other hand has an electrical dipole which interacts with the electric field. The general result of the interaction is the same whether the dipole characteristic is magnetic or electric.

In the lowest energy level state, the O_2 molecule may have one of three values. The transition producing the millimeter absorption are from this triplet ground state to the higher energy levels and all of these energy changes except one are very close to the frequency of 60,000 megacycles per second. The one remaining transition has approximately twice the energy and twice the corresponding frequency. Thus, one oxygen absorption peak occurs at 2.5 millimeters and the rest are grouped around 5 millimeters. At sea level pressure or higher, the absorption lines around 5 millimeters blend together to form a smooth band. At low pressures, the absorption varies erratically with frequency in this region but smooths out at frequencies removed from the resonant ones. Thus the effect of oxygen is limited to a wavelength sector around 5 millimeters and to a small sector around 2.5 millimeters. Again the frequency extent of the absorption is a function of the pressure and to a lesser amount is a function of the temperature. A small amount of continuous absorption occurs but its effect is negligible except for very long paths.

The absorption by water vapor is considerably more complicated because of the vast array of absorption lines which influence millimeter and centimeter radio wave propagation. For water vapor, one absorption line occurs near 1.35 cm and one at 1.63 mm. In addition, there are 149 energy conversions with critical wavelengths between 0.05 and 1.0 millimeters. Individually, these lines contribute little to the EHF loss, but collectively they provide a continuous loss which increases rapidly as the shorter millimeter wavelengths are approached.

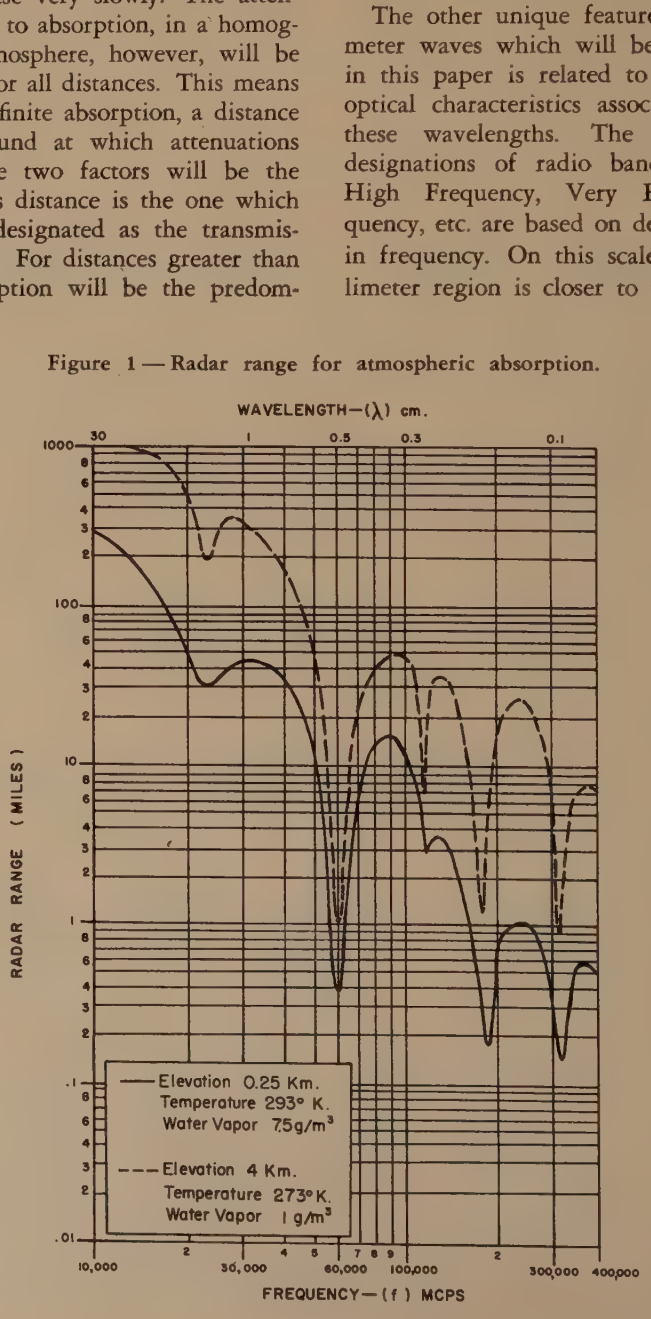
The water vapor content of the atmosphere changes greatly not only with geographical location and elevation, but also with time at a given site. In order, then, to predict the amount of absorption at a particular frequency, it is necessary to know the water vapor content, the temperature and the pressure. The problem is particularly complicated if the transmission is through a significant range of elevations since all of these factors would be variable functions of height. After the absorption has been calculated, the effective range would be a function of the radiated power.

For practical purposes, we have chosen an arbitrary definition of range based on a comparison of attenuation due to divergence and the attenuation due to absorption. The divergence of the beam causes the power density to be inversely proportional to the square of the distance from the transmitter. This means that for greater distances, the power density due to divergence will decrease very slowly. The attenuation due to absorption, in a homogeneous atmosphere, however, will be the same for all distances. This means that for a finite absorption, a distance can be found at which attenuations due to the two factors will be the same. This distance is the one which has been designated as the transmission range. For distances greater than this, absorption will be the predominant factor and for distances less than this, divergence will be the predominant factor.

Using this arbitrary definition, the range as a function of frequency has been plotted in Figure 1 for two typical conditions. The lower curve is for the water vapor content of 7.5 grams per cubic meter at sea level and the upper curve is for the water vapor content of 1 gram per cubic meter at an elevation of 12,000 feet above sea level. These water vapor concentrations would fall in the ranges usually anticipated at these two elevations. From Figure 1, it is seen that very substantial ranges would be associated with some of the longer millimeter wavelength, particularly, for the elevation of 12,000 feet.

The other unique feature of millimeter waves which will be discussed in this paper is related to the semi-optical characteristics associated with these wavelengths. The customary designations of radio band such as High Frequency, Very High Frequency, etc. are based on decade steps in frequency. On this scale, the millimeter region is closer to the optical

Figure 1 — Radar range for atmospheric absorption.



requencies than it is to the standard A-M radio broadcasting frequencies nd many of its features are similar to hose of light waves.

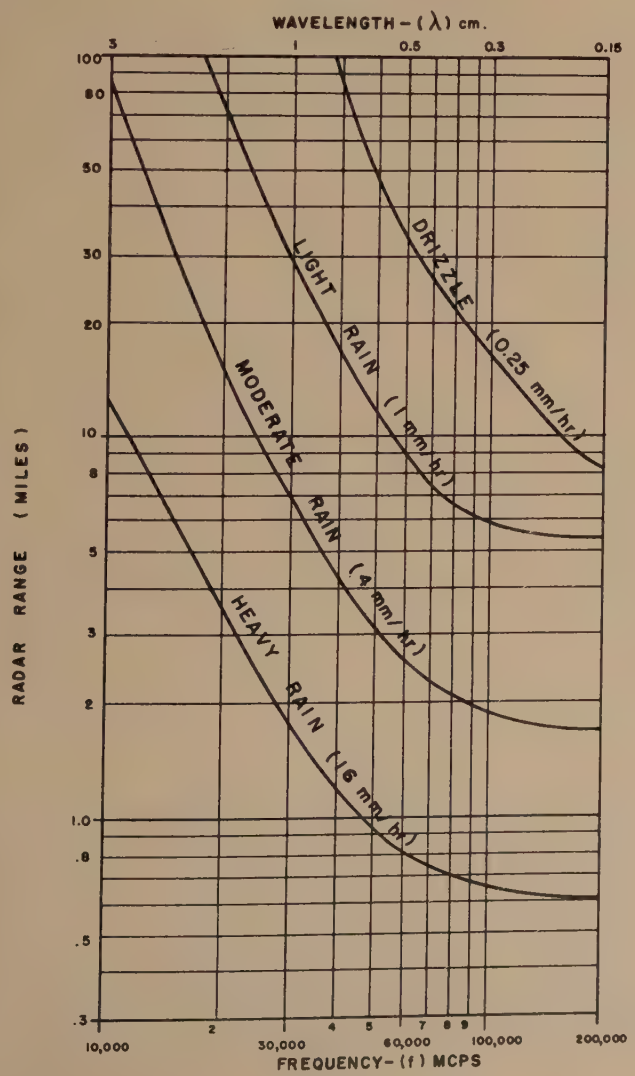
One of these features is the possiility of producing a very narrow eam with a small antenna. Thus, at wavelength of two millimeters, a arabolic reflector one foot in diamter would produce a beam only one alf of a degree between half power oints whereas a fifty foot reflector ould be required for a similar beam idth at a wavelength of ten centieters. This feature suggests the posble use of millimeter wavelengths for pplication where high directivity is esired but space limitation prevent he use of large antennas.

As in the case of light, serious propgation effects are encountered whenver precipitation occurs. For longer adio waves, the diameter of water rops is much less than the radio avelength, but for millimeter waves, he wavelength is comparable to and ometimes smaller than the diameter of raindrops. As a result, rain causes a large amount of absorption and scattering of the incident radio waves. For wavelengths much greater than the diameter of the drops, the attenuation is inversely proportional to the square of the diameter. Very severe attenuation will result in the millimeter region from rain showers and if any proposed millimeter application is to be used in rain, the transmitted power must be adequate to penetrate the area of precipitation.

The size of water drops in a fog is so small that they present comparatively little attenuation. One application tried for millimeter waves has been that of a harbor radar for guiding vessels through fog. The high definition plus the ability to penetrate the fog has made their application a feasible one.

A range through rain can be defined as in the case of the range associated with absorption to be the distance at which the loss due to the rain is equal to the loss due to the divergence of the beam. Figure 2 shows this range as a function of frequency and rainfall rate. This presupposes that the rain is homogeneous over the path. Fortunately many rain showers are of limited areal extent so that the range in rain is not as pessimistic as would be indicated by Figure 2.

Figure 2 — Radar range through rain.



A last disadvantage associated with the shorter wavelengths is the enhanced effects of refraction. Some of the fluctuations may be accounted for by variability of the water vapor absorption of the atmosphere, but the larger part of the refraction results from the focusing and defocusing associated with dielectric blobs.

The atmospheric absorption, the attenuation and scattering by rain and the greater refractive effects are very discouraging to the millimeter system designer. On the other hand, the tremendous bandwidth potential available and the high directivity with small antennas are the encouraging features of millimeter radio waves.

These desirable features may be used effectively in short range radars. Ground mapping from aircraft is a natural since the atmospheric loss will be low from an aircraft to ground, and it is not essential that the mapping be done during rain storms.

Harbor guidance has been mentioned as a possible application for millimeter waves which would be useful under foggy conditions.

The Bell Telephone Laboratories have announced a transmission system using millimeter waves. By using a non-polar gas such as nitrogen in an oversize circular waveguide, the attenuation will be kept small. Other millimeter uses in confined systems could be readily imagined. Indoor transmission, either through pipes or in the open room, might be a desirable and feasible use of millimeter wavelengths.

The resonant characteristics of atmospheric gases might be turned to a useful purpose in space flight. The energy transition of oxygen and water vapor also produce radiation at millimeter wavelengths. A passive detector in space could use this radiation to home on the earth.

In spite of all the limitations discussed in the paper, it seems inevitable that millimeter wavelengths will have many future uses. The development of generators, which is now moving slowly, will be accelerated as particular uses are found for various frequencies in this band.

MEASUREMENT of VARACTOR QUALITY

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Introduction

The characteristics of a varactor element have been shown to be closely equivalent to a voltage-variable-capacitance in series with a fixed resistance,[1] as shown in figure 1. It is also known [2] that the relation between capacitance and reverse-bias voltage is very closely given by $\left(\frac{1}{C}\right)^n = K(V + \phi)$ where C is the capacitance, V the voltage, ϕ a constant; and $n = 3$ for a graded — diffused junction or $n = 2$ for a step-junction (see figure 2).

Uhlir [1] has proposed that the quality rating, or figure of merit for a varactor shall be given by the cutoff frequency $f_c = \frac{1}{2\pi R_s C_{min}}$ and that this, together with a measurement of the capacitance-voltage relationship, is sufficient for most microwave applications. Certainly, if the frequency independence of C and R_s can be relied upon, a Q measurement is a full measure of the efficiency of the element. It is less obvious that C_{min} should be used to define the Q, but since it may be argued that a user may "shape" a voltage waveform to cause the capacitance to vary in a suitable manner, the rating with respect to C_{min} is, in principle, a complete one for the application of varactors in linear circuits such as low-level amplifiers.

In practice, there are minor defects in the assumption of a simple equivalent circuit, but only in exceptional circumstances are these significant. In the forward-bias region, where C is very much larger than C_{min}, the resistance is reduced, and at low frequencies there *may* be sufficient leakage conductance to degrade the capacitance. Hence, to define the low-frequency performance, additional figures of merit are required. However, the initial interest in varactors has been for use at frequencies over 300 megacycles, where the most important factors are the capacitance value and the Q.

The simple equivalent circuit of figure 1 implies that $f_c = Q_m f_m$, where Q_m is the Q at the measurement frequency f_m. However, moderate deviations from this relation are to be expected because of frequency dependent losses in the element or the package. It is desirable to avoid a complex multi-frequency rating, and it is suggested that the best frequency for a general-purpose measurement would be one at which the lowest useful Q prevailed. For a reproducible and conservative rating, it seems wise to choose too high a frequency rather than the reverse.

In the measurement of varactor quality there are inevitable defects in the mount used. There does not appear to be any simple way in which such losses can be evaluated separately from other stray resistive losses although it is possible to assess the contribution of loss in the semiconductor to the total.

The remainder of this paper is concerned with the practical problem of measurement, and it will be shown that a relatively simple procedure has been devised to measure Q of the mounted assembly in the particular test-holder.

Theory of Measurement

About the large variety of methods available, the following brief, and possibly dogmatic, comments are made:

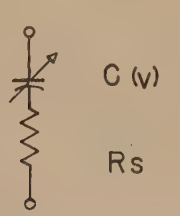

Figure 1 — Equivalent circuit of varactor

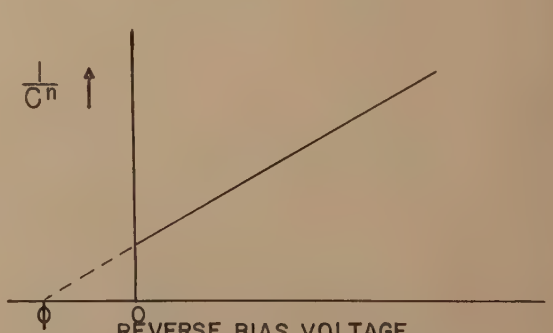

Figure 2 — Capacitance variation with bias

*The material appearing in this paper was assembled while the author was employed by Microwave Associates, Burlington, Mass.

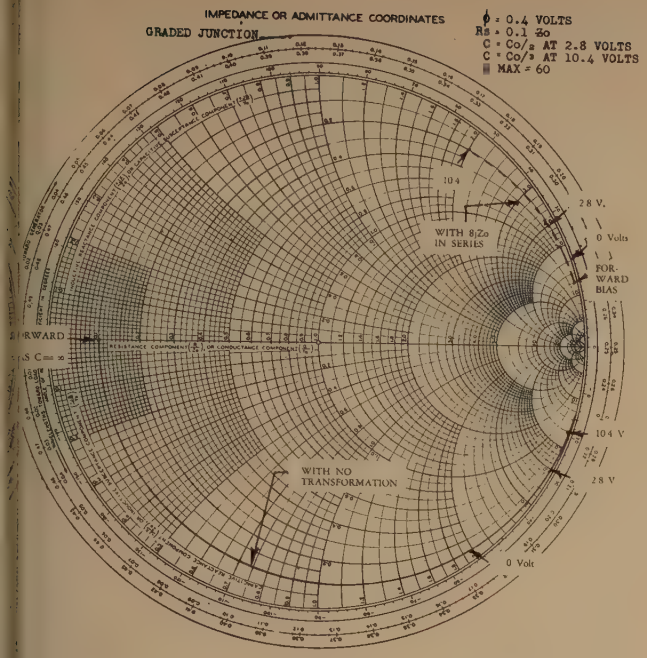

Figure 3 — Ideal varactor at a constant frequency

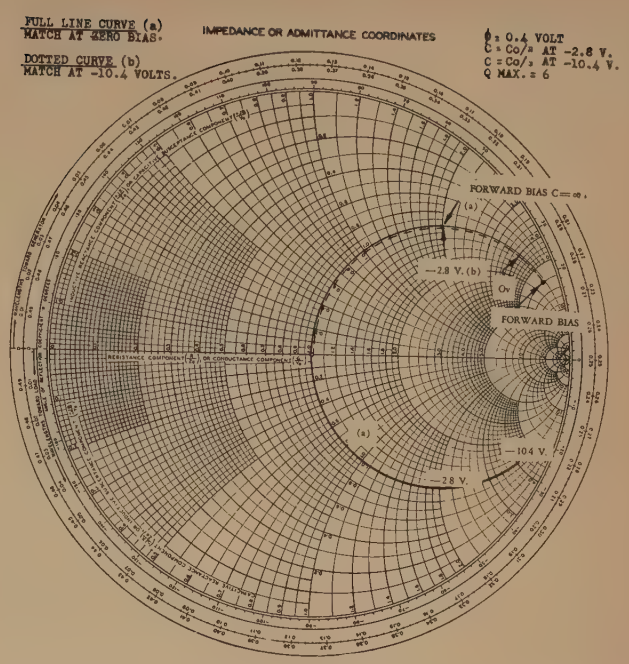

Figure 4 — Ideal varactor impedance transformed to match at suitable bias

Although change in frequency can be measured with precision, it is better to measure change of impedance for a known change of a tuning element of a resonant system at a fixed frequency than it is to measure impedance as a function of frequency. There are many reasons in support of this statement, but the chief of these is that no simple relation holds between impedance and frequency except for simple high-Q elements.

It is easier to measure a low-Q circuit and therefore preferable to measure at a frequency comparable to the cutoff frequency.

In measuring a varactor, an important factor to be nsidered is the nonlinearity of the capacitance ele-ent. Good accuracy is always obtained if the applied voltage does not exceed 1/50 v.r.m.s. but larger ltages can be tolerated for reverse-bias measurements. nce the incident power level which may be tolerated approximately proportional to the square of fre-ency, there is a further advantage in measurement the highest useful frequency.

If a transmission line is terminated in an ideal var-tor, the plot of impedance on a circle diagram is of e type shown in figure 3. Suppose the connections to e varactor introduce stray series reactance, then the cus may change to a very different plot of the type own dotted. Whatever the transformation, it is theo-tically possible to deduce $\frac{\triangle X}{R_s}$ from the plot of im-dance, where $\triangle X$ is the change in value of $\frac{1}{\omega C}$ th bias.

When the basic element ($R - jX$ with X a function bias) is transformed by linear lossless elements, it is ways possible to effect a transformation such that we serve $n(R - jX)$, where n is a real positive number. nce an adjustable line-length and variable reactance n give such a transformation, it follows that we ould always obtain, at some arbitrary plane of a nsmission line, the equivalent of $\{n(R - jX) + jX^1\}$ transformed in phase. Furthermore, similar curves might be obtained either as an impedance or admittance locus, but cannot readily be interpreted except by changing the phase of the locus to fit a constant resistance curve.

The problem with an unknown transformation is to evaluate its parameters with sufficient accuracy. In principle, the transformation can be determined by using *known impedances, with exactly identical transformations.* The nub of this problem is the italicized phrase and a completely satisfactory solution has not been found. The method proposed here by-passes this problem by relying upon the varactor element as a provisional, qualitative impedance standard.

If the stray losses of the case and mount are small or, if appreciable, predominantly in series with the varactor, then we are at liberty to introduce additional lossless transformations with the knowledge that we are transforming what is essentially a constant resistance and variable capacitance element.

It is then justifiable to transform to the $(1 + jX)$ circle as shown in figure 4(a) and (b). By this means, we have effectively converted the impedance-measuring system to a new one of $Z_o = R_s$.

Suppose we match the varactor at any bias point and change the bias to a new value giving a change in reactance $\triangle X = \delta \frac{1}{\omega C_{min}}$. Then the amplitude of the standing-wave ratio gives $\frac{\triangle X}{R_s}$ from which we may deduce $\frac{1}{\omega C_{min} R_s}$. The relation between $\triangle X$ and VSWR is given by

$$VSWR = \frac{\left(4 + \frac{\triangle X^2}{R^2}\right)^{\frac{1}{2}} + \frac{\triangle X}{R}}{\left(4 + \frac{\triangle X^2}{R^2}\right)^{\frac{1}{2}} - \frac{\triangle X}{R}}$$

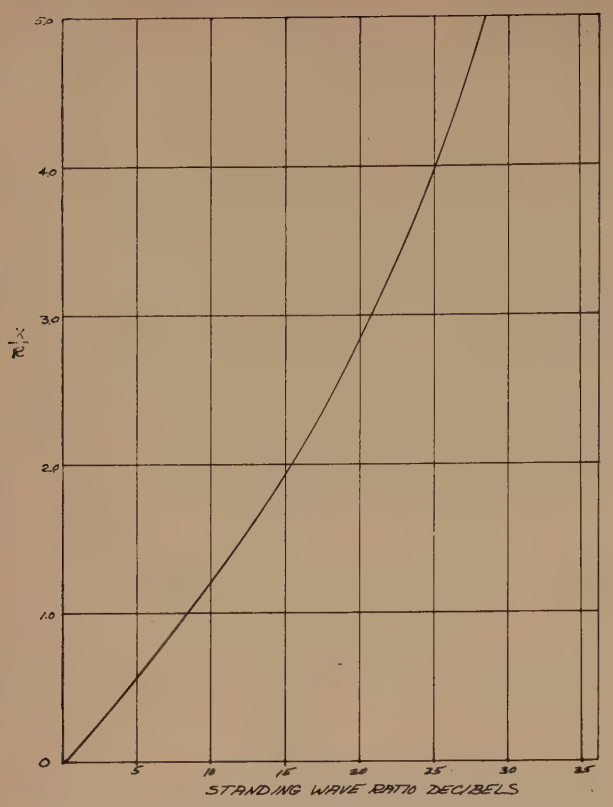

Figure 5 — Standing wave ratio with reactive mismatch

This is derived as follows:

For a mismatch between R and $(R + j\,\triangle X)$, the reflection coefficient $\varrho = \dfrac{j\,\triangle X}{2R + j\,\triangle X}$

The modulus, $|\varrho| = \left(\dfrac{\triangle X^2}{4R^2 + \triangle X^2}\right)^{\frac{1}{2}}$

Hence, the VSWR $= \dfrac{1 + \left(\dfrac{\triangle X^2}{4R^2 + \triangle X^2}\right)^{\frac{1}{2}}}{1 - \left(\dfrac{\triangle X^2}{4R^2 + \triangle X^2}\right)^{\frac{1}{2}}}$

When $\dfrac{\triangle X^2}{R^2} \gg 2$ $\qquad$ VSWR $\approx 1 + \dfrac{\triangle X^2}{R^2}$

A curve of VSWR vs X/R is given in figure 5.

There are many ways in which this technique may be applied to practical problems, some of which will be described in the next section. For the present, it is worth noting that the technique of matching is, in fact, the setting up of a resonant system.

Comparing the resonant and nonresonant techniques, the main comments on each are as follows:

Resonant (Matched) System

1. Any losses in the matching elements will detract from the apparent varactor performance. However, the Q of waveguide resonant structures can be made very high compared with the varactor, and the technique does not require knowledge of the relative magnitude of resonant elements since the reactance change is introduced in the element under test. As an example, the Q of adjustable waveguide stub-sections is limited mainly by the quality of the movable short-circuit. In practice, elements can be made to give reactance of 5 Z_o, with a Q of 100 or greater.
2. The accuracy of measurement depends on the accuracy of matching, but this is the most easily measured impedance condition.

Nonresonant System

1. It is necessary to make phase measurements.
2. If there are significant unknown transformations, it is necessary to correct for these, and the experimental error in doing so may be quite large.
3. The result depends upon calculation of both R & X from the impedance plot, and thereby deducing X/R_s. The error in R is equal to the error in VSWR, and even when there is no error in the deduced value of X this error in R alone is larger than for the resonant system, for which the error in X/R is equal to ½ (error in VSWR).

For both systems the techniques are very similar, and hence normal experimental errors should be of the same magnitude. With the resonant system, though, it is possible to minimize errors in measuring large mismatch coefficients by choosing a small change in bias value (which must, of course, be measured with appropriate precision).

One special source of error is common to both techniques, namely, that it is necessary to introduce bias. If the bias-circuit-decoupling is arranged in the load (varactor) portion of the circuit, there may be losses which appear as deficiency in the varactor.

Briefly, the resonant system offers a simple, practical technique which is capable of considerable accuracy within the limits set by unavoidable parasitic elements. Most lossy elements in the system will be represented as an equivalent resistance in series with the varactor element, but distributed losses which vary in effect as the varactor capacitance is changed (e.g. losses in any line section where the VSWR varies with varactor capacitance) will introduce errors of a complex variety. Hence, provided the loss of any line coupling between the varactor and the tuning elements is small, including dielectric losses of the varactor case, all sources of loss will appear as an increase in equivalent series resistance.

Experimental Technique

The precautions necessary for making accurate measurements of standing-wave ratio or of reflection coefficient are described in the literature.[3] However, a few points are perhaps worth emphasizing as follows:

(a) The decoupling of a probe in a slotted line should be of the order of 30 db if the discontinuity susceptance is tuned out, and considerably greater with an untuned probe.

(b) The measurement of VSWR in a slotted line is independent of mismatch at the source, or generator end, if this mismatch is constant. Particular care may be necessary to ensure that the impedance of the detector is independent of level over the working range.

(c) The measurement of power ratios is most accurate if an attenuator is used to obtain the same input level at the detector. Care is then necessary to ensure that the impedance of the attenuator is constant.

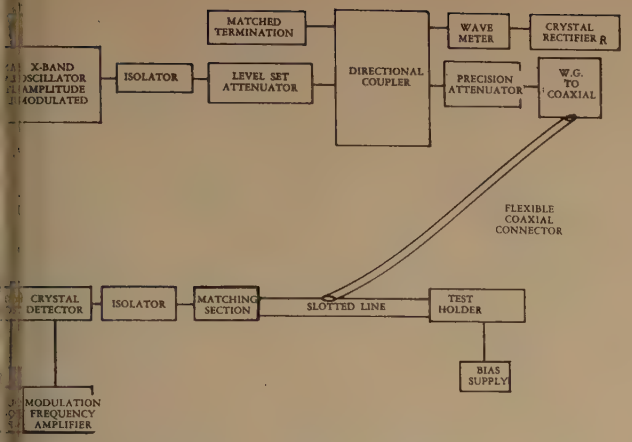

Figure 6 — Diagram of impedance measuring equipment

Because of the low level of signal which may be ap-ed to the varactor, a sensitive receiver is very desir-e, and at the lower freuencies is probably essential. the work to be described, a test frequency of 10,000 was chosen for the reasons outlined previously. At is frequency the power level incident on the varactor y be as high as 10^{-5} watts (10^{-6} watts with perfect iety*). With normal slotted-line measurements, this uld require a detector sensitivity of 10^{-11} to 10^{-12} tts for measuring 30 db standing-wave ratio. How-er, by interchanging the generator and detector,[4] sensitivity requirement is eased to 10^{-9} watts, and s may be achieved by a crystal detector feeding a rrow-band amplifier. It is still necessary to take spe-l precautions because the feed to the probe needs to flexible and yet give negligible impedance change th movement of the probe. A block diagram of a suit-e arrangement is shown in figure 6.

The sensitivity requirements can be eased further by reasing the level in the negative bias region, but, for initial proving of the method, the level was set to $^{-6}$ watts. As alternatives to slotted-line measurements, reflectometer may be used, or a hybrid-balance in hich the unknown reflection is balanced by a variable nuator in front of a movable short. The reflectom-r technique is of particular advantage in setting up e initial matching and, as will be shown, is capable giving excellent results. A hybrid balance technique uld ease the stability requirements on signal level and tector gain but requires an attenuator of precisely-own reflection coefficients independent of the phase the short circuit.

One advantage of the resonant technique is that no ecial care need be taken to ensure that waveguide di-ensions of the test holder or flange fittings between the st holder and the slotted-line section are carefully atched. The tuning elements will take care of any ch discontinuities. In the preliminary work, a fixed aveguide-mount was used for the varactor and a sep-ate matching-element was used. Probe stubs in the nter of the wider wall are unsatisfactory for compen-ting large mismatches because they may introduce rious loss. An E-H tuner, which consists of a wave-

*The level depends on C and Q and can be much higher for gh C and low Q.

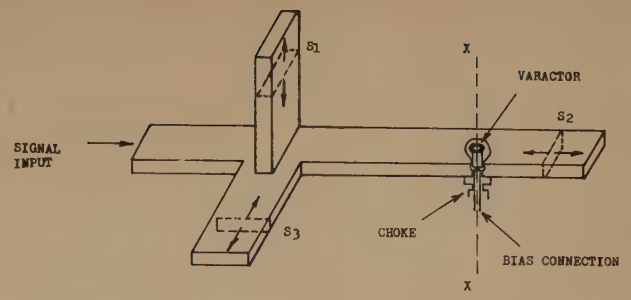

Figure 7 — Varactor test holder using E-H tuner

guide with two waveguide stubs giving the equivalent of a variable series reactance and variable shunt susceptance, has been found adequate for tuning out a mismatch of 10/1 with no detectable loss in the stubs. Hence, one type of resonant-mount system is that depicted in figure 7. When using this arrangement, it is advisable to adopt the following precautions:

(a) Set the movable short S_1 to an optimum position, with the E-H tuner giving negligible transformation. In practice, with a slotted-line, this setting is most easily found by noting the phase corresponding to a pure resistance at plane X-X;

(b) Use a frequency-stable source because the matching system may be very frequency-sensitive.

A better arrangement is that shown in figure 8(a), for there is no ambiguity of settings of the stub-tuners and the matching is less frequency-sensitive. Another alternative is shown in 8(b).

Examples of Results

Figure 9 shows some experimental plots of a low-Q varactor in which arbitrary transformations were used. It appears that fairly satisfactory results are obtained, but considerable judgment is required in choosing the best fit. For comparison, the deduced value obtained by matching and without phase measurements is also shown.

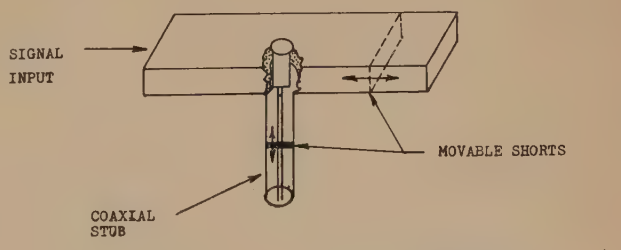

Figure 8a — Alternate form of test holder

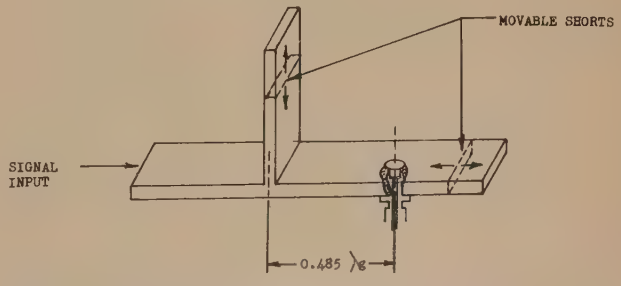

Figure 8b — Alternate form of test holder

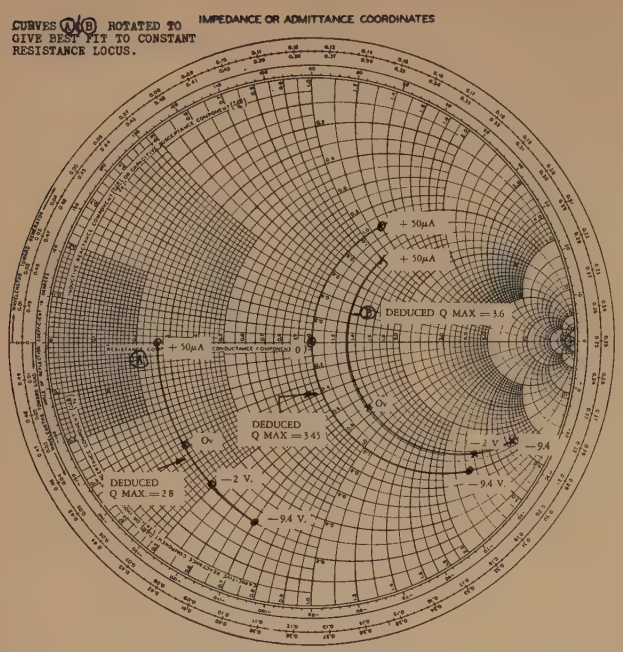

Figure 9 — Impedance plots with arbitrary transformations

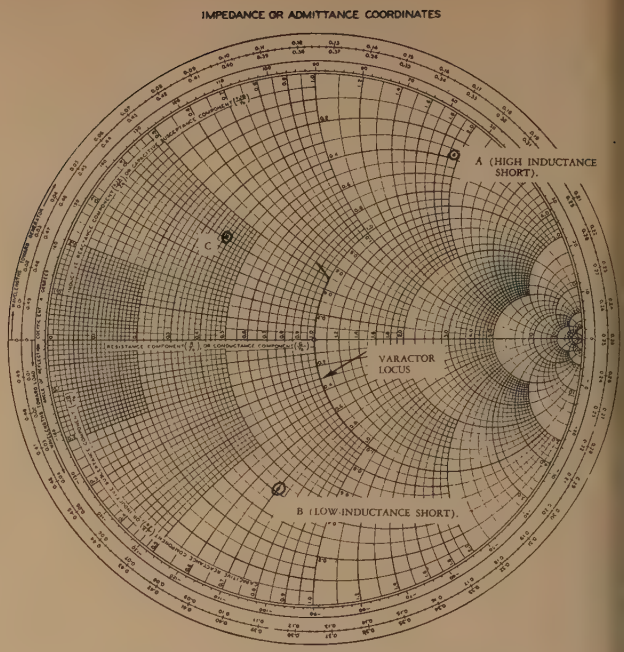

Figure 10 — Short-circuit "references"

Figure 10 illustrates the problem of using a reference short-circuit at this frequency. By taking the average of a large number of measurements, experimentally reproducible results for two different forms of short-circuit were obtained. These are shown at A & B, whereas a result as shown at C was obtained by using the same case and a short of the proper physical shape. The difference between A & B is only 4 x 10^{-11} Henry. Short B was one in which the pin with mounted silicon was replaced by a plain metal pin. Short A was a pin with about .008″ of gold-plated .0035″ diameter tungsten wire and short C was a pin with about .003″ of tungsten wire. The varactor used had a calculated total effective resistance of 2.8 ohms and this is the cause of the sensitivity to small reactance changes. The experimental result shows that the effect of losses outside the silicon was equivalent to 1.1 ohm (0.4 x 2.8).

Figure 11 is a detailed plot of a varactor, set up to match at zero bias. On this plot a phase-difference was obtained by measuring the phase-difference between an open and short-circuit and assuming that the open-circuit would lie at R = ∞. The agreement is excellent but a much easier phase-reference is obtained by assuming that a suitable point lies on the (1 + jX) circle and this is shown for a different unit in figure 12. The satisfactory results for the short-circuit reference in figure 11 is partly a consequence of the fact that the center of the chart in figure 11 is equivalent to 26 ohms.

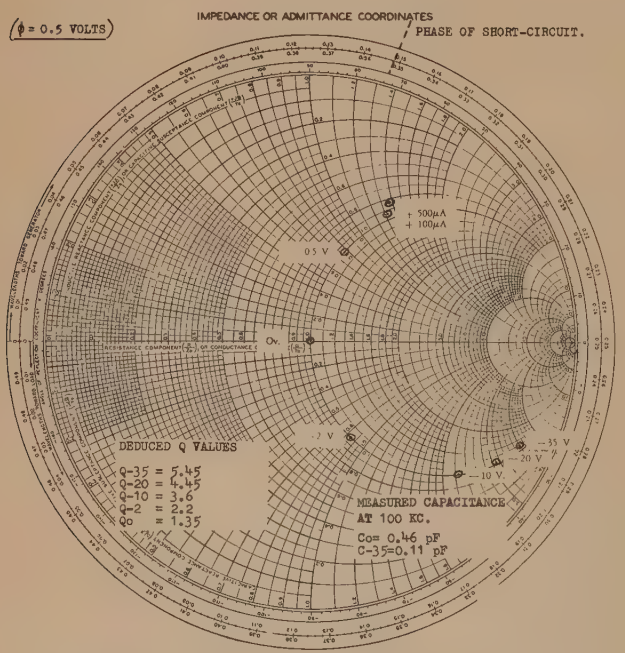

Figure 11 — Impedance plot for high-voltage varactor

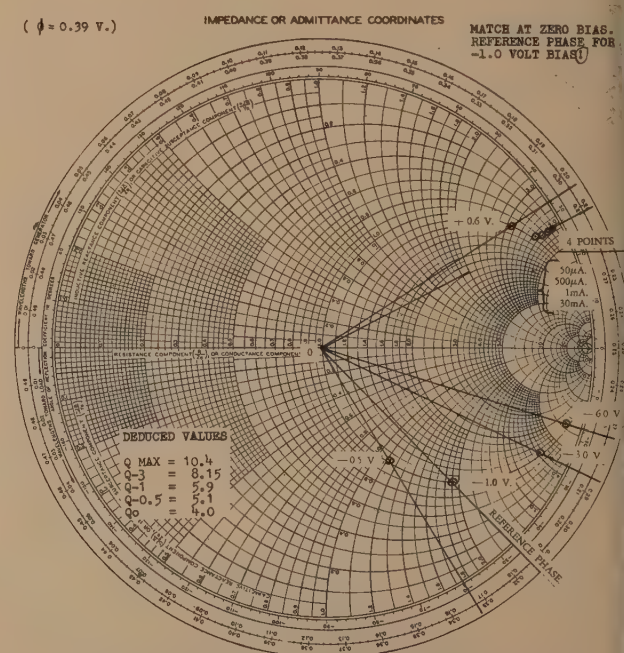

Figure 12 — Impedance locus for high-Q varactor

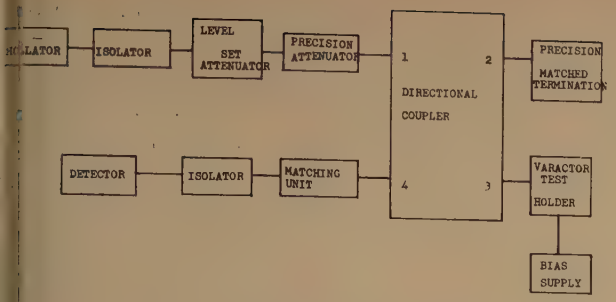

Figure 13 — Reflectometer arrangement

he most instructive features of experimental results graded-junction varactors are that the reactive ges fit the theoretical law for capacitance in the rse bias region, the effect of attenuation on the high iction-coefficient is shown, and the change of resis- e with current in the forward direction is pro- ced. Other experiments in which the same varactor atched at different bias points have shown excellent ement in measured Q value, provided the bias at h is such that there is no current flow.

he errors caused by distributed loss in the line, h gives a reduction in reflection coefficient, may give us error in measuring Q values greater than 5. e correction may be made by taking detailed meas- nents of phase and amplitude, but the easier method reduce the bias-voltage change and multiply the lt by an appropriate factor, as shown below.

y using a reflectometer (directional coupler) the surement is considerably simplified. The schematic own in figure 13. The signal entering port 1 is ely coupled to port 3, and, if there is no reflection ort 3, there is negligible signal received at port 4. a constant level of input, the signal voltage level at 4 is proportional to the reflection coefficient of the ination at port 3, provided port 4 is precisely ched. The procedure is then to adjust the tuning ents for a minimum reading on the detector for an ropriate bias point, say $-V_1$. This "minimum read- may be chosen to correspond to a reflection coeffi- t of .005, since the reflectometer system can be sted for fixed-frequency operation. The bias-voltage nen changed to $-V_2$ and the detector gain set to a suitable reading. The varactor is now replaced a reflection coefficient of 0.99 or better, by means a suitable waveguide switch or removal of the ctor, and the calibrated attenuator adjusted to give same reading on the detector. In this way, most line- nuation of the forward and reflected waves is com- sated.

Ve then have:

$$A = \frac{1}{|\varrho|^2} = \frac{4 + (\triangle Q)^2}{(\triangle Q)^2}$$

re A = attenuation change in available powers ratio

$\triangle Q$ = equivalent Q for change from $-V_1$ to $-V_2$.

he varactor capacitance law is known, then V_1 and may be chosen so that the value of Q at a suitable nt may be deduced and the attenuator may be cali- ted directly. For example, if $\phi = 0.4$ volt, $n = 3$,

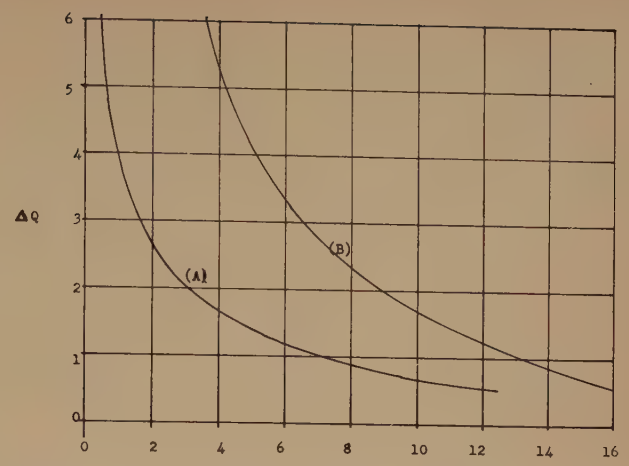

Figure 14 — (A) shows attenuation in decibels; (B) shows linear movement of polarization attenuator in arbitrary units.

and V_1 is set to 12.1 volts and V_2 to 6.0 volts, we have $\frac{C_1}{C_2} = \left(\frac{6.4}{12.5}\right)^{1/3} = \frac{4}{5}$.

This gives $\triangle X = \frac{1}{\omega C_1}\left(1 - \frac{4}{5}\right)$ and hence Q at -12.1 volts $= 5\ \triangle Q$.

A very convenient scale shape is obtained by using a polarization attenuator, and this is illustrated in figure 14.

Conclusion

A varactor can be rated in terms of a Reactance/Resistance ratio at high microwave frequencies. It has been shown that a measurement, including case and mount losses, can be performed with ease and accuracy at 10,000 mc. The method is absolute in $\triangle Q$ provided the unit is a true variable-reactance in series with a constant resistance. With improvements in varactors it will be desirable to measure at still higher microwave frequencies.

Further work on microwave rating of varactors will be primarily concerned with reductions in extrinsic losses. Though quality measurements are desirable at lower frequencies for some applications, it is probable that tests to control varactor deficiencies can be effected more readily by other means than Q measurements. Such tests, in conjunction with a microwave measurement, should give adequate guarantee of performance at all rated frequencies.

References

1. A. Uhlir, Jr. The Potential of Semiconductor Diodes in High Frequency Communications. Proc. IRE, vol. 46, no. 6, June 1958, p. 1009.
2. W. Shockley. The Theory of PN Junctions in Semiconductors and PN Junction Transistors. Bell System Tech. J. vol. 28, July 1949, p. 435.
3. For a useful bibliography see: IRE Standards on Antennas and Waveguides. Waveguide & Waveguide Component Measurements, 1959. Ref. 59 IRE 2. S1. Published in Proc. IRE vol. 47, no. 4, April 1959.
4. E. L. Ginzton. "Microwave Measurements," McGraw Hill, 1957, p. 236.

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PRESENT STATE OF ART IN HIGH POWER TRAVELING-WAVE TUBES

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PART II

III. EXPERIMENTAL DATA ON "O" TYPE HIGH-POWER TW TUBES

A. Present State of Art in Loaded Waveguide Circuits

In the previous section, a number of slow-wave circuits suitable for possible interaction with high velocity beams were discussed. In this section, test results on a number of experimental tubes will be presented, indicative of the state of art in early 1959. Although the results are not complete, they are representative of a large fraction of the effort in the area of periodically-loaded waveguide circuits. The circuits to be described include an operating voltage range from 10-130 kv. Most work to date has been on pulsed devices, but increasing attention is being given to the achievement of CW capabilities up to the kilowatt power levels.

The four classes of circuits which have been most extensively exploited to date include two types of fundamental forward-wave circuits (the Cloverleaf and the Reversed-Coupled Loop Circuits) and two types of spatial harmonic circuits (the inductive slot circuit and the Modified Interdigital Line).

Experimental results are tabulated in Table II. The devices are divided into two classes: "Kilowatt-type" tubes, operating from about 10-30 kv, and "Megawatt" type tubes, operating in the 80 kv range and up.

	Voltage	Circuit	Hot Band Width (3 db)	Max. Sat. Efficiency	Low Level Gain	Focusing	Power Output	Notes
"Kilowatt"-Type Tubes	5 kv	Interdigital line	23%		40 db	Sol.	100-150 watt CW	
	10 kv	Interdigital line	20-25%	10%	25-30 db	Sol.	1 kw peak	
	13 kv	Cloverleaf	1.5%	19%	15-20 db	Sol.	1.8 kw CW	No Sever
	16 kv	Single Slot Folded Line	13%	14%	20-25 db	Sol.	2-5 kw peak	Single Sever
	17 kv	Double Slot Folded Line	12%	12%	30-35 db	PM	3-6 kw	Single Sever
	25 kv	Single Slot Folded Line	13%		18 db	Sol.		
	25 kv	Single Slot Folded Line	10%		>30 db	PM		Multiple Sever
"Megawatt"-Type Tubes	50 kv	Double Slot Folded Line	8%	20%	20-30 db	Sol.	300 kw S-band	No Sever
	85 kv	Double Slot Folded Line	4% 9%	33% 28%	35-40 db 25-30 db	Sol.		No Sever
	85 kv	Single Slot Folded Line	13%	25%	20-30 db	Sol.		Single Sever
	90 kv	Double Slot Folded Line	9%	14%	20-25 db	PM		Single Sever
	100kv	Double Slot Folded Line	9.6%	15%	20-30 db	Sol.	1 MW S-band	Distrib. Loss
	120kv	Cloverleaf	10-12%	25-30%	30 db	Sol.	2 MW S-band	Severed
	125kv	Centipede	15%	30%	20-28 db	Sol.	2-3 MW S-band	

TABLE II High Power "O" Type Traveling Wave Tube

1. Kilowatt-Type Tubes

Seven different types of tubes are given in this category in Table II. The widest hot bandwidth obtained to date is approximately 20 percent, using the circuit in Figure 10B. Typical efficiencies are in the 10 percent range for the wideband tube, 15 percent for a moderate bandwidth tube and as high as 20 percent for narrow band (1.5%) tubes without a sever. These tubes are typically of the severed type of construction, giving 20-30 db gain and in most instances employ solenoid focusing. The power outputs range from 1 to 30 kw of pulsed power.

Considerable interest in lightweight focusing of these types of circuits has resulted in developments of both periodic electrostatic and magnetic focusing schemes. Several electrostatic focusing schemes have been proposed, and are described in a later section. Periodic magnetic focusing has advanced somewhat more rapidly and has actually been reduced to practice on a number of high power developmental tubes.

2. Megawatt-Type Tubes

The remainder of experimental tubes listed in Tab II deal with TW tubes operating in the 50 kv ran and up. Most attention to date has been devoted to c cuits of the spatial harmonic type, using either single double slot coupling, and to circuits of the reversed-ty loop coupling such as the Cloverleaf and the Centipe The first megawatt-type tube (of the spatial harmo type) was constructed at Stanford in 1952 and repor by Chodorow and Nalos,[11] Figure 4. Subsequent versi of this tube achieved 1 megawatt of peak power at band[26] over a 10 percent bandwidth. The Cloverleaf tu since its conception by Chodorow and Craig at Stanfo has been reduced to practice not only there, but also SERL, England, Varian Associates and the General Elect Microwave Laboratory. The most recent addition to t group is the "Centipede" circuit evaluated recently Stanford.[27]

Maximum bandwidth achieved to date is about 15 p cent at the 3 db points, with saturation efficiencies betwe 20 and 30 percent. With somewhat reduced bandwid say 5 percent, saturation efficiencies in excess of 33 perc have been achieved, with gains in excess of 40 db. T has been achieved with both fundamental forward-w and spatial harmonic circuits. The increasing activity this field promises to extend the present state of rather rapidly. The theoretically predicted efficiencies

55 percent (without any circuit refinements) have been sely approached in loss-free laboratory type tubes of d' gain and will undoubtedly be duplicated in more prac- ul tubes in the near future.

Present Problems

Although the basic interaction principles have been cessfully demonstrated and the usefulness of high power ices of the loaded waveguide type is unquestioned, eral areas of improvement are indicated. These include:

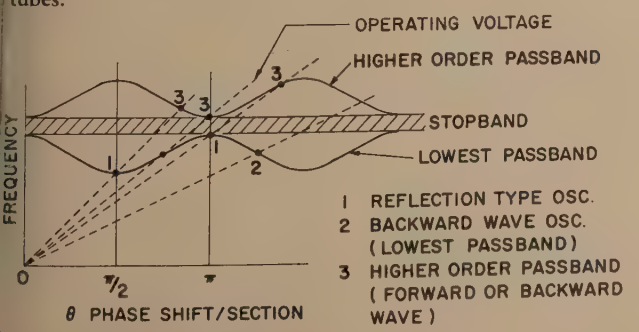
1. Increased Stability
2. Enhanced Efficiency
3. Increased Gain

Stability

Contrary to the klystron, the TW 'tube employs a con- uous circuit, with the output not electrically isolated m the input. Output load variations can give rise to dback and reflection-type oscillations in the tube. One cessful method of isolating the input from the output cuit employs the use of a short internal termination erred to as a "sever." If properly constructed, it is able of absorbing relatively high average powers. Car- ized ceramics in intimate contact with the wall of the cuit have been used for this application. Stable gains 30-35 db have been achieved with single-sever type construction, and 40-45 db gains with multiple severs. ith well designed couplers and terminations, the prob- n of reflection-type oscillations can be avoided. For rt-circuit load stability, however, the output section st be relatively short, resulting in a reduction in effi- ncy. Without the use of severs, gains of 25 db have n achieved over a 10 percent bandwidth with good bility, provided load isolators are used or load mis- tches do not exceed VSWR of about 1.5. Reflection- e oscillations can occur at any frequency in the pass- nd where serious mismatches occur, but more frequently d to occur near the band edges where it is more diffi- t to match to the circuit. By proper design of the pass- nd characteristics, it is usually possible to select an op- ting voltage far enough removed from synchronism at cutoff frequencies.

Aside from reflection-type oscillations, instabilities sed by backward-wave interaction can occur. In pulsed vices, for example, as can be seen by referring to Figure , as the voltage builds up, synchronism occurs for a mber of branches of the Brillouin diagram, both in the west passband and in higher-order passbands of the cuit. If the r-f impedance is sufficiently high, voltage- nable oscillations will be present at frequencies corre- sponding to the backward-wave branches. As the voltage builds up to its operating value, i.e., away from synchronism for backward-wave interaction, the oscillations cease. This behavior gives rise to what are referred to as pulse-edge oscillations which occur only on the buildup and decay of the pulse. The frequency of these oscillations can usually be selected by design of the cutoff frequency of the circuit. The existence and intensity of these oscillations are determined by the geometry of the circuit and often make it desirable to select a circuit which may not be optimum from the impedance point of view. Numerous methods are being explored to eliminate these types of oscillations. If the rise time of the voltage pulse is sufficiently fast, the oscillation does not have adequate time to build up and does not occur. With the use of a grid, it is possible to control the current separately, and not pulse the current on until the voltage has reached its operating value. If non-reciprocal loss can be employed in the circuit, the start oscillation current can be made to exceed the operating current and not interfere with the forward-wave amplification. More simply, since the oscillation frequently occurs outside the passband, frequency selective loss methods can be used to advantage. Oscillations in higher-frequency passbands can also be suppressed using this method. From the point of view of high average powers, these solutions are not as satisfactory as avoiding the oscillations entirely. In narrower band circuits (5-10 percent) this has been accomplished by proper selection of coupling slot geometry, but in wider band high-power tubes a number of approaches have been suggested, most of them involving some change in the periodicity of the slow-wave circuit, either smooth or abrupt, designed to alter the r-f behavior near the troublesome region. It is perhaps of interest to note that the average power to date is more likely to be limited by the output window than the internal termination.

gure 15 — Oscillation problems in periodically loaded TW tubes.



2. Efficiency

The question of efficiency in high power devices is of utmost importance. Although efficiencies on short, loss-free TW tubes have exceeded 40 per cent, most TW tubes of the loaded waveguide type are in the 10-30 percent range. Yet if we compare this, for example, with klystron art, we see that on the basis of development time since first reduction to practice, these figures are about equivalent. The theoretical efficiencies which can be achieved, as calculated by Tien,[28] Rowe,[29] and Webber,[30] for example, are not far different from the klystron, and numerous circuit refinements exist to further enhance the efficiency. These include various means of tapering the slow-wave circuit to maintain synchronism between the beam and circuit, reaccelerating the beam by means of d-c voltages on the circuit to maintain the bunches in proper phase relation to the circuit wave, and depressing the collector potential to recover some of the kinetic energy of the spent beam. One such scheme reported by Sterzer,[31] has resulted in a saturation efficiency of 56 percent using a doubly segmented collector.

Other methods, similar to the sorting mechanism of crossed-field devices, also suggest themselves in conjunction with periodic focusing. By operating near the stopband, it is possible in principle to reject certain slow electrons in unfavorable phases to the walls of the circuit, before they have a chance to extract energy from the wave. Cutler[32] has shown that it is these electrons which

finally form a secondary bunch which extracts energy from the circuit, while the primary bunch continues to give energy up.

Not least of all, improvements in the r-f circuit impedance, especially at higher power levels, are required to achieve better efficiency over a broader frequency range. The use of high perveance beams, both of solid and hollow geometries also indicate an effective increase in the gain parameter which should be reflected in achieving higher efficiencies.

3. Gain

A large fraction of high power loaded-waveguide TW tubes are of the single sever type of construction. With reasonably good terminations and couplers, gains of the order of 25-30 db are easily achieved with good stability for 10-20 percent bandwidth, and 30-40 db for 5-10 percent bandwidth. Higher gains can be achieved by multiple-sever type of construction. Gains in excess of 50 db have been reported by Bates [33] using this type of construction. It is not unreasonable to suppose that gains typical of klystron performance will be approached by experimental tubes within the next several years.

IV. FUTURE TRENDS IN HIGH POWER TRAVELING-WAVE TUBE DEVELOPMENT

Although the results attained to date are impressive, the long range potential of the high power TW tubes has not nearly been reached. The present trend in the research and development effort indicates forthcoming improvements in the following areas:

1. Evolution of a unified circuit approach.
2. Exploitation of composite types of tubes, referred to under a general heading of hybrid tubes.
3. Incorporation of recent improvements in beam formation, including the use of hollow beams and multiple beams.
4. Application of beam focusing innovations, such as periodic focusing, to achieve more compact and lighter design.
5. Demonstration of long life and good reliability under field conditions.

The factors involved in some of these areas will now be discussed.

1. Evolution of a Unified Circuit Approach

Although a considerable number of slow-wave circuits have been examined, no general criteria have been developed by which one circuit can be rated over another. There is no known limit on the theoretically achievable gain-bandwidth product and no unified approach dealing with all circuits has yet been developed. As clearer understanding of these concepts is developed we can look forward to higher impedance circuits capable of higher gain per unit length, higher efficiency, and greater bandwidth. Moreover, it will become possible to select an optimized circuit for a given application without having to resort to an empirical approach. Until that time arrives, however, continued progress is to be expected in evolution of new specific circuit configurations. One such area includes more effective utilization of presently known circuits whose usefulness is limited by nearby passbands where interaction is to be avoided. A successful general method of tackling this mode interference problem will be a large step forward. Although some understanding of behavior near the cutoff region has been obtained,[34] a more detailed explanation under actual operating conditions is desired. A greater understanding of behavior of attenuators under large signal conditions is also required to fully exploit the high power capabilities of TW tubes. These areas merely serve to indicate that we are nowhere near the point where an optimized design can be carried through analytically, let alone allow exploitation of all the possible refinements.

2. Composite Type (Hybrid) Tubes

a. Generalized Interaction

Between the high-gain klystron, the large-bandwidth TW tube, and the high-efficiency crossed-field amplifier there exists a vast grey area where investigators have tried to fill specific needs by combining the advantageous features of each in a composite device. There is much merit in this approach, and as better understanding of each device develops, a larger trend in this direction is to be expected. Combination of high power TW tubes with klystrons have already been attempted by Gittins,[35] who used a TW buncher combined with an output cavity system, Yadavalli,[36] who used a stagger-tuned klystron buncher with a TW output system, and others.

A second class of composite tubes includes devices which employ generalized forms of coupling and decoupling circuits, as well as a generalized interaction "drift" space. These are referred to as "Extended Interaction Devices." The input and output circuits may be of the cavity type or of the TW type and can be either terminated, resonant or employ feedback to achieve higher impedance. The interaction space may be either a simple drift tube or a generalized impedance wall. One such example is Walker's narrow-band Easitron circuit which utilizes inductive wall amplification over a narrow frequency range. A wider-band version of the inductive-wall amplifier of 8 to 10% bandwidth, utilizing a loaded-waveguide circuit has also been developed.[37] Resistive-wall amplifiers have also been demonstrated,[38] and possibilities of using rippled stream or rippled wall space-charge amplifiers have also been considered. Plasma amplifiers can also be regarded in terms of an impedance wall amplifier, with the important property that the plasma entirely penetrates the beam causing good coupling independent of frequency. It is hard to estimate the impact of this work on high power TW devices, but it has served to stimulate thinking in terms of generalized impedance-wall interaction.

b. Multiple Function Devices

Another class of TW devices encompasses tubes for special functions, such as voltage selective amplification, frequency mixing, frequency multiplication, etc. Although these concepts have to date only been applied to helix type experimental tubes, the basic principles are generally valid for loaded-waveguide circuits. Both forward-wave and backward-wave type of interaction can be considered. The advantage of backward-wave interaction is in the fact that relatively high gain narrow-band amplification can be obtained, with electronically variable center frequency. Such backward-wave selective amplifiers have obvious advantages at low levels in receiver systems but at present do not appear of great use at high powers. Helix type traveling-wave tube frequency-multipliers have

n built giving useful multiplication ratios of ten to en with substantial gain.[39] Frequency mixing and fre- ncy division have also been accomplished[40] in double x tubes of the forward-wave type. One such mixer e a conversion gain of 18 db from a 2.7 kmc input 1.2 kmc output with a bandwidth of 300 mc. This her suggests the exploitation of simultaneous amplifica- of several signal frequencies in a single conventional W tube or a multi-segment tube in which each section optimized to enhance interaction in a given frequency ge.

hese modifications are illustrative of the methods by ich special functions may be accomplished in future h-power TW tubes.

Modified TW Interaction

The last class of composite type devices concerns pure W interaction and points to future trends in improve- nt of "conventional" single-severed or distributed-loss e TW tubes. By the use of multiple severs, it is pos- e to enhance gain to values approaching klystron gains. modifying the circuit periodicity of different sections the tube, either using severs, or matched tapered trans- ns, it is possible to approach the stagger-tuned tech- ues of klystrons and enhance gain in desired portions of band. In fact, shaping the gain-frequency character- cs can be accomplished by this method. In addition, is possible to taper the circuit periodicity in a given tion to achieve higher efficiency or greater stability.

Improvements in Beam Formation

Most high-power TW tubes developed today employ id beams of conventional perveance, 1-2.5 x 10^{-6}, and tain no means of controlling the current separately m voltage. For pulsed power applications with low rage power requirements, conventional mesh grids may employed but as higher average powers become avail- e, the development of non-intercepting current-control ctrodes will assume a greater importance. The develop- nt of low μ electrodes, i.e., those which require nearly l cathode-anode voltage to control current flow, is rela- ely easy and has been demonstrated in klystrons[41] but achieve higher μ's, cathode modifications such as the ierced Type" cathode,[42] employing a single or a number biased posts projecting through the cathode itself, have be employed. The reduction to practice of such devices s not as yet been made and it does not appear that greater than perhaps 5-10 will be obtainable by this thod. Such devices, however, are receiving increasing ention, inasmuch as they greatly enhance the flexibility the tube, allowing the use of more compact modulators switching purposes, and the achievement of more rapid e times.

With improvements in cathode materials, such as dis- nser cathodes, it has been possible to raise the CW rat- g of cathodes from a fraction of an ampere to several peres per square centimeter. In addition, the use of thodes of the magnetron injection type[43] have made ssible large effective beam convergences, since emission obtained from a large surface. A cylindrical form of

ch a gun is shown in Figure 16. Ratios of $\frac{L}{a}$ of the der of 10 have been obtained, indicating that CW emis-

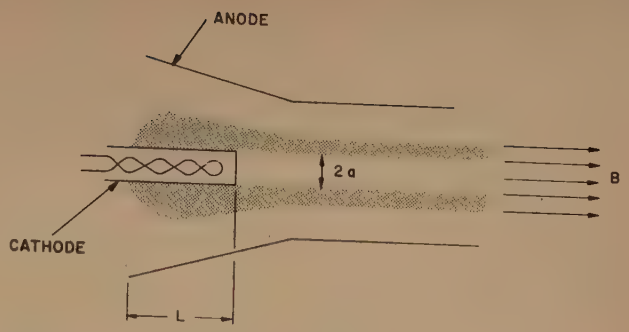


Figure 16 — Schematic of magnetron injection gun.

sion capability with several megawatts of beam power is feasible at lower microwave frequencies.

Recently, greater interest has been shown in the use of hollow beams for high power microwave tube applications. With confined non-convergent flow, high perveances can be achieved, since the limit of perveance of a solid beam applies to a unit square of the hollow beam. Thus thin beams can easily be made with perveances in excess of 10-20 x 10^{-6}, approaching the limiting perveance due to space-charge depression. The use of the magnetron injection principle allows the incorporation of hollow beams into megawatt-type TW tubes with conservative current densities. The additional advantages of the use of a hollow beam are:

a. High perveance, i.e., lower operating voltage for a given application. It is indicated that megawatt type tubes may operate at voltages below 50 kv.

b. Better interaction, since the gain parameter C^3 is the ratio of r-f impedance to the beam impedance. The beam impedance is greatly reduced by the use of high perveance, thus the gain parameter is increased. This results not only in larger gain per unit length, but also in larger bandwidth and higher potential efficiency.

c. Use of circuits of larger transverse dimensions, i.e., higher ultimate power capabilities. Solid beam interaction is limited to values of $\gamma a \cong 1$, whereas with thin hollow beams values of $\gamma a \cong 3$ or greater can be used.

d. Means of beam focusing which are inherently simpler and more efficient. For example, Harris flow focusing or periodic electrostatic focusing may be used if a center rod can be inserted into the structure.

These advantages are sufficiently attractive to warrant exploitation of some loaded-waveguide circuits for this application. One such circuit has been given by Field[44] and several other possibilities have been described by Disman[45]. These are shown in Figure 17.

The spiral waveguide is useful for narrow band applications but interfering backward-wave modes must be eliminated before wideband operation can be realized. The simple disc-loaded waveguide with circular coupling aperture offers good possibilities for interaction with a thin hollow beam but has not yet been eval-

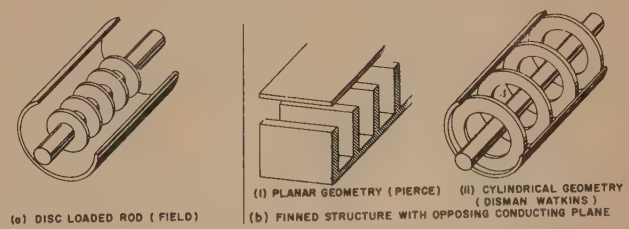

(a) DISC LOADED ROD (FIELD)
(i) PLANAR GEOMETRY (PIERCE)
(ii) CYLINDRICAL GEOMETRY (DISMAN WATKINS)
(b) FINNED STRUCTURE WITH OPPOSING CONDUCTING PLANE

Figure 17 — Some circuits suitable for hollow beam interaction.

(a) 4-HELIX CIRCUIT (PUTZ) (b) PROPOSED 4-BEAM LOADED WAVEGUIDE CIRCUIT

Figure 18—Some TW circuits suitable for multibeam operation.

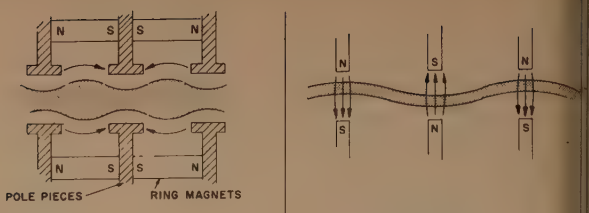


Figure 19 — Periodic magnetic focusing systems.

uated experimentally. The disc-loaded rod, proposed by Field, has also not as yet been evaluated in a high power device, but a closely related circuit, the cylindrical version of a finned structure with an opposing conducting plane has been tested with modest success by Watkins and Disman.[45] Unfortunately, the results were marred by the presence of a higher-order TE mode whose impedance is comparable to the coaxial mode for which the tube was designed. Other circuits will undoubtedly be proposed for hollow beam interaction and efforts will be directed to the elimination of higher order modes which invariably occur in circuits of large transverse dimensions.

The use of hollow streams is only one of the methods of increasing the available beam power. The next step which suggests itself is paralleling single tubes either of the solid beam or hollow beam type. This has been done with some success over narrow frequency ranges with klystrons. It is not a trivial matter to tie separate TW tubes together and expect proper operation in parallel over wide frequency ranges. It may be possible to provide external components which compensate for the different phase shift through the tube due to somewhat different current or circuit geometry from tube to tube, but a more promising approach perhaps lies in the area of paralleling the slow-wave circuits together internally and coupling them r-f wise in a single envelope, so that only a single wave exists along the composite multi-beam circuit. This has been done successfully with a 4-helix circuit by Putz in a 100 watt CW X-band tube, and the concepts employed have the analogy in loaded waveguide circuits. The 4-heli circuit is shown in Figure 18a, and a proposed extensic to a loaded waveguide circuit is given in Figure 18b.

4. Beam Focusing Innovations

Perhaps the most significant recent development beam control has been the evolution of periodic focusir both of the electrostatic and magnetic type. This typ of beam focusing is becoming increasingly popular low and medium power helix tubes. To date, for exampl commercial tubes of 1 watt CW power at X-band (Hu gins) and 1 kw peak at S-band (Hughes) have bee successfully focused using ferrite ring magnets. As pra tical materials of higher coercive force become availabl we can expect to be able to focus smaller beams of high power density. Using some of the more recent type fe rite materials such as Indox V and VI, the range at whi solid beams of conventional perveances can be PM focus has gradually been extended. Beam transmission in exce of 95 per cent has been obtained at 25 kv with sol beams of 0.100″ diameter using this type of focusir The circuit used to produce the focusing fields may completely independent of the r-f circuit, or it may

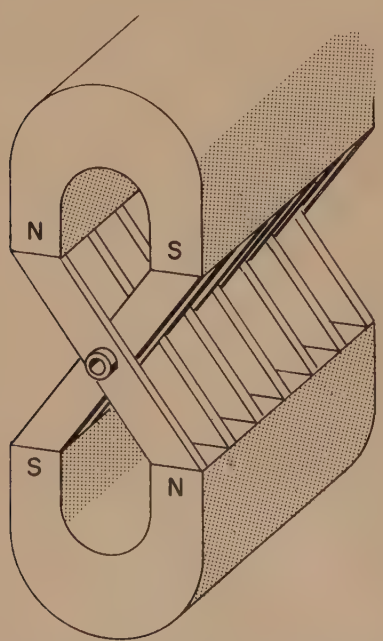


Figure 20a — Crossed web periodic magnetic focusing scheme.

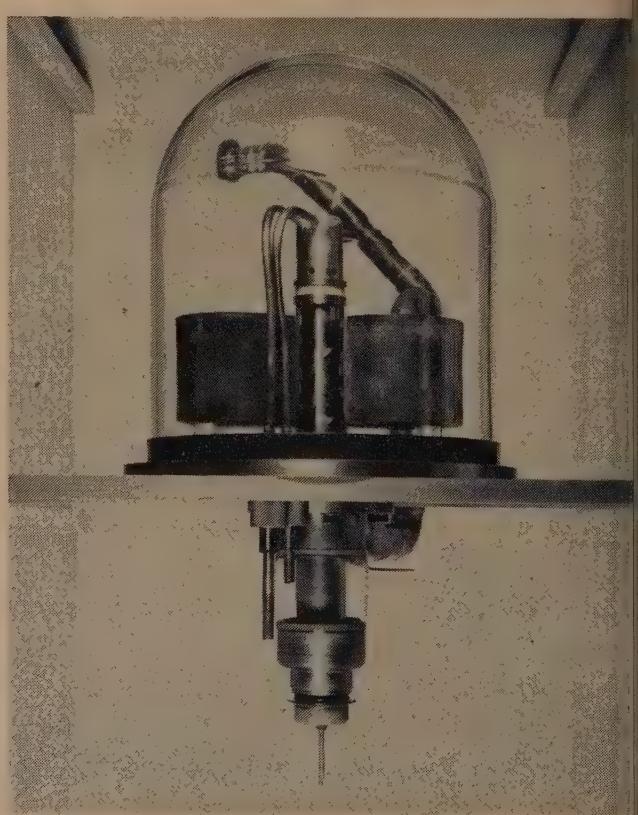


Figure 20b — Bell-jar beam tester for PM focusing experimer

ntegral part thereof. In the magnetic case, Figure 19A, achieve focusing of high power tubes with presently lable material, methods of obtaining high peak axial ls in excess of the coercive force of the material must found. One such method has been reduced to practice[46] ch employs conventional Alnico horseshoe magnets ling a "crossed-web" magnetic circuit as shown in Fig- 20A. With this scheme, peak axial fields in excess of 0 oersteds have been obtained, which are adequate to s megawatt-type beams at microwave frequencies. A m tester employing this type of focusing is shown Figure 20B. In a specific application, this innovation resulted in replacing a 75 pound liquid cooled solenoid suming 2 kw of power with a magnet weighing less n 20 pounds. Focusing schemes which involve trans- se periodic fields rather than axial fields have also been posed[47] (Figure 19B). This type of beam focusing ults in an undulating beam trajectory rather than a oling one, and to date has not been fully evaluated.

Electrostatic focusing methods have also been success- y applied to experimental low and medium power TW es. In principle, this method results in greater com- tness, since no magnets whatsoever are required and power supplies to set up the desired electric potentials not draw any appreciable power. In fact, in cases ere the beam need only be maintained over a relatively rt distance, such as in a two or three cavity klystron, l where the beam is not constrained to a fixed diameter, beam may be maintained by its own space charge hout the use of any external focusing fields (Figure A.) This unfortunately has little application to TW es, due to their greater electrical length.

Purely electrostatic systems, which do not use periodic ds have also been developed. In one configuration, ure 21B, space charge is overcome entirely by the trifugal action of the beam. Novel types of low power plifiers and oscillators, which use helical beams, can focused by this method. The Helitron[48] (which uses novel type of interaction referred to as "E-Type") and ratron[49] (which uses conventional "O" type interac- n) belong to this group. If a center conductor can be orporated in the structure, Harris flow focusing can be d with a hollow stream (Figure 21C). Another type electrostatic focusing used at low powers with mod- te success is Slalom focusing,[50] Figure 21D; the focus- g action depends on the fact that the equipotentials

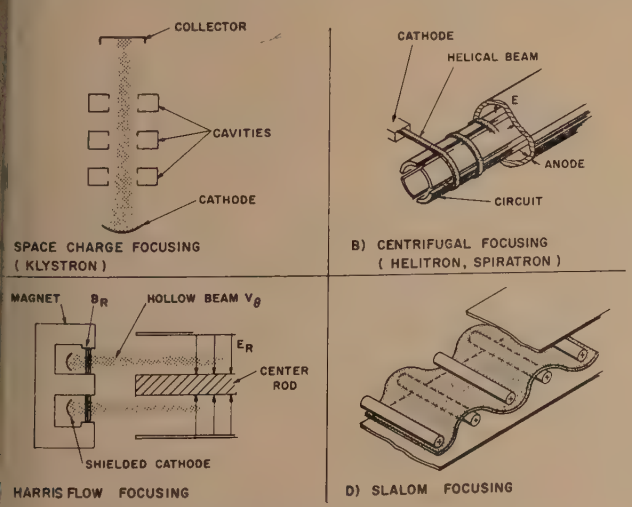


Figure 21 — Electrostatic focusing systems.

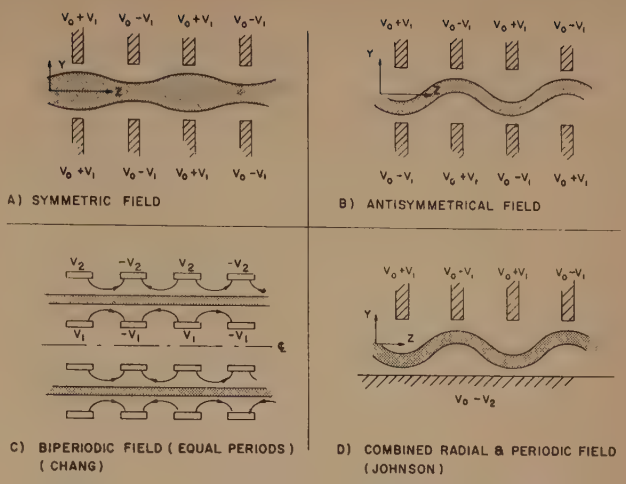

A) SYMMETRIC FIELD
B) ANTISYMMETRICAL FIELD
C) BIPERIODIC FIELD (EQUAL PERIODS)
(CHANG)
D) COMBINED RADIAL & PERIODIC FIELD
(JOHNSON)

Figure 22 — Periodic electrostatic focusing systems.

around a linear array of charged wires correspond to the electron trajectories of a weaving ribbon beam. Beam transmission of 97 percent was achieved with a perveance 2 x 10^{-6} gun to date, although r-f results in low power oscillator were somewhat disappointing.

Several types of periodic electrostatic focusing schemes are described in Figure 22. These may be used to focus either sheet beams or cylindrical beams. The symmetrical configuration, Figure 22A, will cause the beam to scallop, whereas the antisymmetrical configuration, Figure 22B, will cause the beam to undulate. The symmetric system, Figure 22A, has been used by Tien[51] to focus a beam inside a bifilar helix. More recently, workers at RCA[52] have used the same principle in the so-called "Estiatron." To date, devices of this type giving 10 watts at S-band with saturation gains of the order of 20 db have been built. The anti-symmetrical system, Figure 22B, has not yet been used experimentally. The biperiodic system proposed by Chang,[53] Figure 22C, employs two counteracting periodic fields. This gives better cancellation of space charge fields, which can compensate for potential depression inside the beam. Using two bifilar helices to set up the required electrostatic field, with the outer circuit used for r-f propagation, a beam of perveance 2 x 10^{-6} was focused with 97 percent transmission and 10 db of gain at S-band.

A combination of radial electric and periodic electric fields has also been investigated by Sauseng[54] and Johnson,[55] Figure 22D. With this scheme, a hollow beam can be focused by the action of inward forces from the outside rings and by adjusting the inner cylinder potential to cancel space-charge forces. This type of focusing has resulted in 97 per cent beam transmission of a hollow beam of perveance 6 x 10^{-6} and is currently being applied to a design of a 200 watt CW helix amplifier at 300-600 mc.[56]

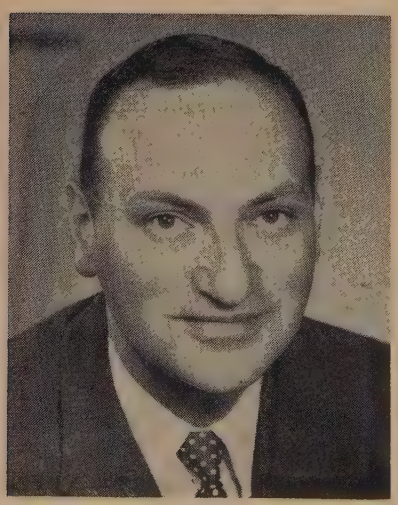
The variety of focusing schemes indicates a growing interest in this area, and it is safe to predict that electrostatic focusing systems will be applied to higher power tubes in the near future. One such experiment with a simple interdigital line, segmented into two separate insulated sections, has been made by Barnes.[57] At 1000 volts, he obtained 90 percent beam transmission with a perveance of 0.7 x 10^{-6}. At present, in conjunction with periodically loaded waveguide circuits, greater over-all simplicity of assembly is achieved using periodic magnetic focusing, but both areas are being vigorously investigated.

V. CONCLUSION

Although it is impossible to cover completely the high power traveling-wave tube art in a paper of this type, enough evidence has been given to indicate a large growing activity, whose impact will be felt in the entire microwave field. The demand for high power capability with good efficiency, compactness and reliability as well as large gain and bandwidth, have stimulated a number of new ideas which involve extension of existing concepts as well as completely new concepts. One of these is the interaction of periodically perturbed beams with unloaded transmission lines, referred to as "fast-wave" interaction. Although we can expect other innovations in the area of basic interaction, perhaps the greatest impact within the next several years will be felt in the area of development and quantity production of high power TW tubes with life and reliability equivalent to existing low power microwave tubes.

Bibliography

26. M. Chodorow, E. J. Nalos, S. P. Otsuka, R. H. Pantell, "The Design and Characteristics of a Megawatt Space-Harmonic TW Tube," IRE, PGED, vol. ED-6, no. 1; January, 1959.
27. M. Chodorow, D. K. Winslow, F. Pierce, "High Power Broadband Tube Structures," Stanford University Microwave Laboratory, Scientific Report #8, Report No. 536; August, 1958.
28. P. K. Tien, "A Large Signal Theory of TW Amplifiers Including the Effects of Space Charge and Finite C," BSTJ no. 34, vol. 35, p. 349; March, 1956.
29. J. E. Rowe, "Design Information on Large Signal Traveling-Wave Amplifiers," Proc. IRE, vol. 44, no. 2, pp. 200-210; 1956.
30. S. E. Webber, "Electron Bunching and Energy Exchange," Trans. IRE, PGED, vol. 4, January, 1957.
31. F. Sterzer, "Improvement of TW Tube Efficiency through Collector Potential Depression," IRE, PGED, ED-5; October, 1958.
32. C. C. Cutler, "The Nature of Power Saturation in TW Tubes," BSTJ 35, pp. 841-876; July, 1956.
33. D. Bates, PGED Conference, Washington, D.C.; October, 1958.
34. R. W. Gould, "Characteristics of TW Tubes with Periodic Circuits," IRE, PGED vol. ED-5 no. 3, p. 186; July, 1958.
35. J. F. Gittins, "Some Experiments with a TW Buncher Klystron," SERL Journal no. 42; October, 1956.
36. S. V. Yadavalli, "Private Communication," to be published soon.
37. E. J. Nalos, "A Hybrid Type TW Tube for High Powe Pulsed Applications," IRE, Trans. on Electron Devices, ED- no. 3; July, 1958.
38. C. K. Birdsall, G. Brewer, A. Haeff, "The Resistive Wa Amplifier," Proc. IRE, vol. 41, no. 7; July, 1953.
39. D. J. Bates, "A Traveling-Wave Frequency Multiplier," Sta ford University Microwave Laboratory Report No. 38 April, 1957.
40. R. W. Degrasse, "Frequency Mixing in Microwave Bea Type Devices," Stanford University Electronic Laborato Technical Report No. 386-2; July 28, 1958.
41. G. Badger, "A New Method for Modulating Electron Beam for Pulse Applications and Linear Amplitude Modulatio Systems," paper presented at IRE Network Convention, N.Y March 26, 1957.
42. C. Susskind, private communication.
43. J. F. Hull, "High Current Density Beam Tube," U.S. Pate No. 2, 632, 130; March 17, 1953.
44. L. M. Field, "Slow-Wave Structures for Traveling-Wa Tubes," Proc. IRE, vol. 37, pp. 34-40; 1949.
45. M. J. Disman, "A Preliminary Investigation of a High Pow Hollow Beam TWT Amplifier," Stanford University Ele tronics Laboratory Report No. 458-1; November 4, 1958.
46. R. M. Phillips, paper presented at PGED Conference, Wa ington, D.C.; October, 1958.
47. P. Sturrock, "Theory of the Focusing of Sheet Beams Periodic Fields," Stanford Microwave Lab. Report ML N 462, November, 1957.
48. P. A. Watkins, G. Wada, "The Helitron Oscillator," Pro IRE, vol. 46, no. 10, p. 1700; October, 1958.
49. F. S. Tchernov, "The Spiratron, a TWT with Centrifug Electrostatic Focusing of the Electron Beam," paper presente at International Congress on Microwave Tubes, Paris; Jun 1956.
50. J. S. Cook, R. Kompfner, W. H. Yocum, "Slalom Focu ing," Proc. IRE, vol. 45, no. 11, p. 1517; November, 195
51. P. K. Tien "Bifilar Helix for Backward-Wave Oscillators Proc. IRE, vol. 42, pp. 1137-1143; July, 1954.
52. D. J. Blattner, F. E. Vaccaro, "The Estiatron, an Electr statically Focused Medium Power TW Amplifier," IRE, N tional Convention Record, vol. 6, part 3, p. 101; 1958.
53. K. K. N. Chang, "Biperiodic Electrostatic Focusing for Hig Density Electron Beams," Proc. IRE, vol. 45, p. 152 November, 1957.
54. O. Sauseng, "Investigations on Electrostatic Focusing of Ele tron Beams," Lab. for Ultra-High Frequency Tubes, Siemen and Halske, A. G.; Munich, Germany.
55. C. C. Johnson, "Periodic Electrostatic Focusing of a Hollo Electron Beam," IRE, PGED, vol. ED-5 no. 4, p. 233; O tober, 1958.
56. G. Novick, Ph.D. Dissertation, Stanford University.
57. C. Barnes, "Periodic Focusing of Electron Beams," Stanfo Electronics Research Lab., Technical Report No. 33; M 3, 1954.



The IRE announced recently that Dr. Nalos has been named recipient of t 1960 W.R.G. Baker Award given to the author of the best technical paper publishe in the *IRE Transactions* of the Professional Groups.

Dr. Nalos' paper was entitled, "A Hybrid Type Traveling-Wave Tube f High Power Pulsed Amplification," which appeared in the July, 1958 issue of t *IRE Transactions on Electron Devices.*

Microwave Component News from SYLVANIA

22 TYPES OF FERRITE DEVICES NOW IN FULL PRODUCTION AT SYLVANIA

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Tee Circulator—FD-TC531—typical of Sylvania's tee circulator and isolator line is this model, which operates at 24 KMC, weighs only three ounces and is 1½" x 1½" x ¾". It is less expensive than conventional phase shift circulators. The line covers from 5.4 to 26 KMC.

Waveguide Isolator—FD-5213A—this miniature X-band isolator is representative of Sylvania's success in miniaturizing these important components. Units from 2.6 to 26 KMC are available.

Coaxial Isolator—FD-151P—representative of Sylvania's coaxial line, it gives octave coverage. The units in this line exhibit unequalled electrical performance and cover the range from 1 through 11 KMC.

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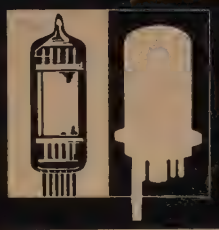

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INDUSTRY NEWS

1960 IRE INTERNATIONAL CONVENTION SET FOR MARCH 21-24

The Institute of Radio Engineers has announced a change in the title of its annual Convention from IRE National Convention to the IRE International Convention. The change reflects the fact that the IRE now has 22 Sections and 6,000 members outside the United States.

March 21 through 24 have been selected as the dates for the 1960 IRE International Convention, which will again be held at the Waldorf-Astoria Hotel and New York Coliseum in New York City. More than 60,000 engineers and scientists from 40 countries are expected to attend what has become the world's largest technical meeting and exhibition.

A compehensive program of 275 papers, covering the most recent developments in the fields of all 28 IRE Professional Groups, will be presented in 31 sessions at the Waldorf-Astoria and the Coliseum. The high point of the program will be a special symposium on "Electronics — Out of This World" to be held Tuesday evening, March 22. The symposium will be conducted by Ernst Weber, President of the IRE for 1959, and a panel of leading space electronics experts. The complete program will be announced in January.

The Radio Engineering Show, filling all four floors of the Coliseum, will accommodate approximately 850 exhibitors. Some $15,000,000 worth of the latest electronic equipment will be on display, most of it for the first time.

The convention will get under way with the Annual Meeting of the IRE on Monday morning, March 21. Dr. Lloyd V. Berkner, President of Associated Universities, Inc., will be the featured speaker.

The social events will include a "get-together" cocktail party Monday evening and the annual IRE banquet Wednesday evening, both in the Grand Ballroom of the Waldorf. The banquet will feature the presentation of IRE Awards for 1960, including the Medal of Honor to Harry B. Nyquist, former Bell Telephone Laboratories engineer, and the Founders Award to Haraden Pratt, Secretary of the IRE.

An entertaining program of tours, fashion shows and matinees has also been arranged for wives of visitors.

— *mwj* —

IRE HUMAN FACTORS IN ELECTRONICS SYMPOSIUM

e IRE Professional Group on Human rs in Electronics will hold its first An- Symposium on Human Factors in ronics in New York City the evening hursday, March 24th and all day Fri- March 25th, 1960.

ose interested in presenting papers or ggesting symposia should correspond on as possible with:

Mr. R. R. Riesz, Chairman
Papers Procurement Committee
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Murray Hill, New Jersey
or with
Mr. J. E. Karlin, Chairman
Meetings Committee
c/o Bell Telephone Labs.
Murray Hill, New Jersey

— *mwj* —

G. DOMSITZ JOINS WEINSCHEL ENGINEERING

yron G. Domsitz has joined Wein- l Engineering as Executive Vice- ident, according to an announcement e by Mr. B. O. Weinschel, President he rapidly growing firm which spe- zes in precision microwave calibra- equipment.

Ir. Domsitz was previously Vice-Pres- t, Engineering, of Simmonds Aero- ories of Tarrytown, New York.

rior to joining Simmonds, Mr. Dom- was employed for more than ten s in ordnance development work at National Bureau of Standards. With transfer of the military research work the National Bureau of Standards to Department of Defense in September, 3, Mr. Domsitz was appointed Asso- e Technical Director of the Diamond lnance Fuze Laboratories.

fr. Domsitz, who resides at 5355 ks Hill Road, Bethesda, Maryland, is raduate of Augustana College, Sioux ls, South Dakota and has completed duate work in physics at the Uni- sity of Iowa.

— *mwj* —

HARRIS-INTERTYPE ACQUIRES PRD

Harris-Intertype Corporation announced that it has completed an agreement for the acquisition of Polytechnic Research and Development Company from the Polytechnic Institute of Brooklyn.

"PRD," as Polytechnic Research and Development is generally known, is a leading producer of microwave test equipment for advanced work in the communications field, both commercial and defense, including space and missile programs.

George S. Dively, chairman and president of Harris-Intertype, said purchase of the Brooklyn company will be largely for cash, although the price was not disclosed. The transaction is expected to be completed within a few weeks.

The acquisition is the sixth since 1953 for Harris-Intertype, one of the largest U.S. manufacturers of printing and publishing equipment and also a leading producer of broadcasting equipment.

Dr. Ernst Weber, president of Polytechnic Institute of Brooklyn, is also president of PRD. An international authority on microwave electronics, he is the 1959 president of the Institute of Radio Engineers, whose 76,000 members make it the world's largest engineering society.

According to Dively, present plans are to continue the operation of PRD by the present organization as a decentralized subsidiary of Harris-Intertype. Both Dively and Weber said they hope to maintain the traditionally close relationship between PRD and Polytechnic Institute of Brooklyn.

— *mwj* —

VARIAN ASSOCIATES REPORTS EARNINGS, SALES INCREASES

Varian Associates reported a 67 percent increase in earnings and a 32 percent increase in sales volume for the year ended September 30, 1959, over the prior year.

Consolidated sales for the current year were $38,130,311 compared to $28,985,-714 for 1958. Sales and earnings include operations of Bomac Laboratories, Inc., in which Varian has an 80 percent interest, for the entire period.

Net income after taxes for 1959 was $2,518,169 or 81 cents per share on 3,125,650 shares outstanding. In 1958, net income was $1,503,727 or 48 cents per share on 3,103,698 shares (after giving effect to the share issued in exchange for Bomac Laboratories, Inc., and to the two for one stock split in June 1959), outstanding at September 30, 1958.

In making this announcement, chairman of the board, Dr. Edward L. Ginzton stated all operating functions of the company had contributed to the increased profit margins.

At year end, Varian Associates and its subsidiaries were employing total assets of $30,184,340, including a net investment in plant and equipment of $9,592,-422. Floor space at Varian's four plant

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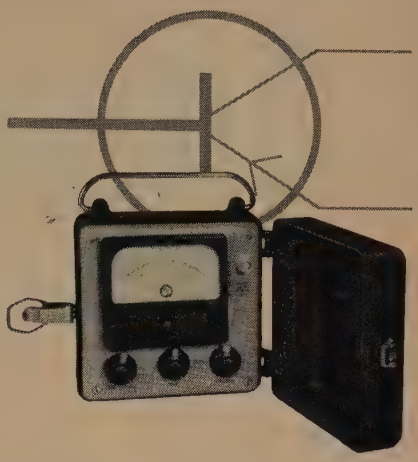

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W-163-1C-1	9.2-9.4 KMC	20 DB Min.	0.5 DB Max.	1.25 Max.
W-117-2A-1	9200-9400 MC	18 DB Min.	0.3 DB Max.	1.30 Max.
W-269-2A-1	5.975-6.425 KMC	20 DB Min.	0.7 DB Max.	1.25 Max.
W-569-1B-2	16.0-17.0 KMC	I-III 30 DB Min. II-I 20 DB Min.	0.5 DB Max.	1.20 Max.

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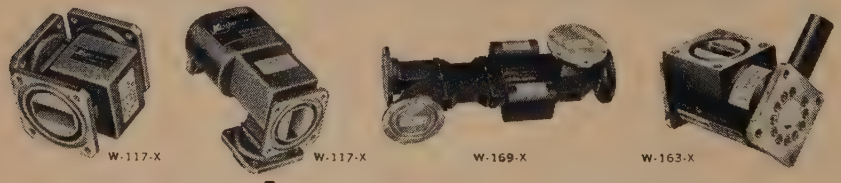

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locations totalled 500,000 square feet with 80,000 square feet of additional space under construction and 200,000 square feet scheduled to be added in 1960.

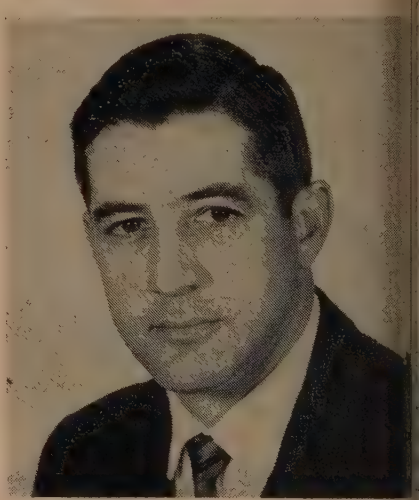
Varian's backlog for products and services was $19,229,885 at September 30, 1959, compared to $17,218,498 at September 30, 1958. Order receipts during the fourth quarter were $10,623,468 compared to $9,222,434 a year ago.

During 1960, Ginzton said, Varian expects to maintain this upward trend in sales volume reflecting the growing demands in the fields of high power communications systems, research laboratory equipment, space technology and advanced weapons systems. Through advanced research and engineering effort, further diversification of its product lines, continued attention to product improvement and cost reduction, the company anticipates that profits in 1960 will show further gains over those realized in 1959.

— *mwj* —

GORHAM APPOINTS BASLER

Mr. Joseph A. Basler has been appointed Contracts Manager for Gorham Electronics, division of Gorham Manufacturing Co. of Providence, R.I.



Mr. Basler will supervise the handling of all contracts and will assist Robert S. Gordon, Sales Manager, in Administration matters.

Prior to joining Gorham Electronics, Mr. Basler was associated with Daystrom Instrument and the W. L. Maxson Corp. where he had extensive experience in the contracts and sales departments.

— *mwj* —

ALFRED ELECTRONICS APPOINTS RUSH S. DRAKE ASSOCIATES

Alfred Electronics has appointed Rush S. Drake Associates to represent the Palo Alto, California manufacturer of microwave test instrumentation throughout the Northwest.

Drake with headquarters in Seattle will cover Oregon, Washington, Idaho and British Columbia.

— *mwj* —

TIONAL COMPANY APPOINTS HANNIGAN

he appointment of Joseph H. Hanni- to the post of Director of Radar and -red Communications, Technical Li- Division, was announced by Joseph Quick, president of National Com- , Inc., engineering, development and facturing firm of electronic systems communications.

r. Hannigan comes from Gabriel Needham, Mass., where he was sales neer of its electronics division since . Prior to that he spent three years the Department of Defense, Navy rtment, Bureau of Ships, Washing- where he held a staff position of ronics engineer. His responsibilities ded: the planning, designing, and installation of countermeasures, ed missile radar control, remote con- equipment, radiation warning sys- infra-red devices. He was also con- nt in nuclear power instrumentation control.

fore moving up to the Department efense, Mr. Hannigan was with the Department as an electronics engi- with numerous duties in Navy elec- cs covering guided missiles, warning ms and communications.

ior to that Mr. Hannigan was as- d to Radiation Laboratory, Massa- etts Institute of Technology as elec- cs engineer in the antenna section r Dr. L. C. Van Atta.

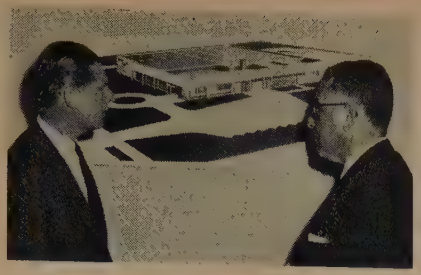
— *mwj* —

URNDY PLANT IN BELGIUM TO SERVE EUROPEAN COMMON MARKET

nstruction will start this fall on a plant at Malines, Belgium, in which dy Electra S.A., European subsidiary urndy Corporation, Norwalk, Conn., manufacture electrical connectors for in the Common Market nations, it been announced by Sidney Wolberg, president, overseas operations.

e interest shown by both national local governments, as well as labor uctivity, transportation, and avail- ty of materials and services were by Mr. Wolberg as among the rea- for selecting Belgium and the Ma- area. The plant site is between erties already occupied by du Pont Procter and Gamble.

heduled for completion in the spring 960, the plant will house a complete ine shop with tool and die facilities, s and assembly operations and a house. It will serve offices across ern Europe, including Antwerp, Zur- Cologne, Rotterdam, Stockholm, Os- Copenhagen, Hamburg, Berlin, Karls- , Nurnberg, Milan and Turin. Plans prepared by Eugene De Witte, arch- , of Belgium, with the cooperation Massari Associates, Stamford, Con- icut.



Jean A. Tilot (left), consul-general and director of the Belgian Industrial Information Service in New York, is discussing the plant with Sidney Wolberg, the company's vice-president, overseas operations.

Initially, the building, of steel, glass and concrete construction, will have 27,000 square feet of floor space on a 16 acre plot, leaving ample room for expansion. The north and west walls, while of permanent construction, will be easily removable when future growth makes it necessary to increase the size of the plant.

A feature of the plant will be a covered bicycle rack for the convenience of the workers. "Many workers in Belgium still use bikes, motorcycles, or scooters," Mr. Wolberg said, "but we expect they'll need automobile parking space in just a few years, and we're prepared for it."

In addition to the subsidiary in Belgium, Burndy's affiliated companies in Europe include BICC-Burndy Ltd., in England; Burndy-Elektro (GmbH), in Western Germany; and Burndy Elektra A. G., in Switzerland.

— *mwj* —

BOSTON IRE PLANS SPRING MICROWAVE LECTURES

The Boston Section of the IRE is planning a Spring series of lectures devoted to microwaves. Present plans include six 2-hour talks. Topics will include: systems, tubes, components and antennas.

The lectures will be survey in nature and will include the latest state of the art information.

The lectures will be delivered by a nationally known expert in each specialty. The actual dates of the series have not been set but it is expected that it will take place on consecutive weeks between the National IRE show in New York and the PGMTT Symposium in San Diego.

— *mwj* —

"VARACTOR" DIODE USED IN SOLID-STATE ULTRA-HIGH FREQUENCY RADIO RECEIVER

An ultra-high frequency mobile telephone radio receiver designed around solid-state devices was described by L. G. Schimpf of Bell Telephone Laboratories, speaking at the annual meeting

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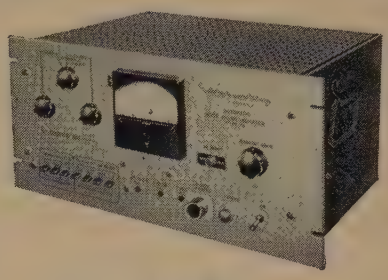

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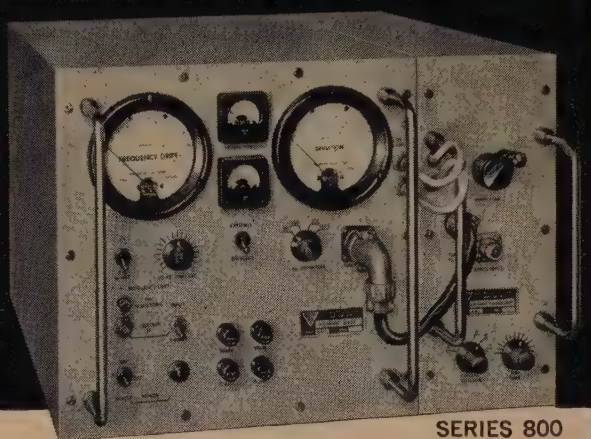

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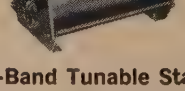
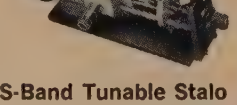
Stability....less than 5 cps peak



L-Band Tunable Stalo
Frequency Range 1000-1500 mc
Tuning Range.....10%+
Stability.....4-8 cps peak



S-Band Tunable Stalo
Frequency Range 2000-3200 mc
Tuning Range.....10%+
Stability.....7-10 cps peak

Write for Bulletin M-3

PITLOG

PITOMETER LOG CORP.

237 Lafayette Street New York 12, N. Y.
Advanced Instrumentation Since 1927

Circle Reader Service Card 34

of the Professional Group on Vehicular Communications of the Institute of Radio Engineers. Mr. Schimpf told how new devices such as the "varactor" diode can be used in a solid-state radio receiver designed to operate at around 900 mc.

The receiver is of the double-conversion superheterodyne type with a first i-f centered at 63 mc, and the second at 10.7 mc. It has a sensitivity of about one microvolt for 13 db of quieting. All amplification, conversion, and frequency generation operations are fulfilled by using solid-state devices.

To provide the high local oscillator frequency necessary for the first conversion, a three-step chain is employed, consisting of a crystal-controlled transistor oscillator, a transistor doubler and a frequency tripler. It is in this frequency tripler stage that the special characteristics of the varactor diode are employed to advantage.

A silicon diode is used as the first mixer, and the first i-f consists of a two-stage transistor amplifier with a gain of about 35 db. The second oscillator is transistorized and crystal-controlled, providing a frequency of 73.7 mc. This frequency, when mixed with the first i-f at 63 mc., gives the second i-f of 10.7 mc. This second i-f, which is also transistorized, serves as a limiter when FM signals are being received.

— *mwj* —

DR. JOSEPH HULL PROMOTED BY LITTON

Promotion of Dr. Joseph Hull to Director of the Research Laboratory of the Litton Industries Electron Tube Division was announced recently by Dr. Norman Moore, Division General Manager.

Dr. Hull has been Chief Scientist in San Carlos since April 1955, working primarily in the fields of backward wave oscillators and crossed-field devices. He is a graduate of the University of Wisconsin (BSEE), Rutgers University (MSEE) and Polytechnic Institute Brooklyn (DSEE). Prior to joining Litton Industries, Dr. Hull was employed with the General Electric Research Laboratory and the Signal Corps Engineering Labs.

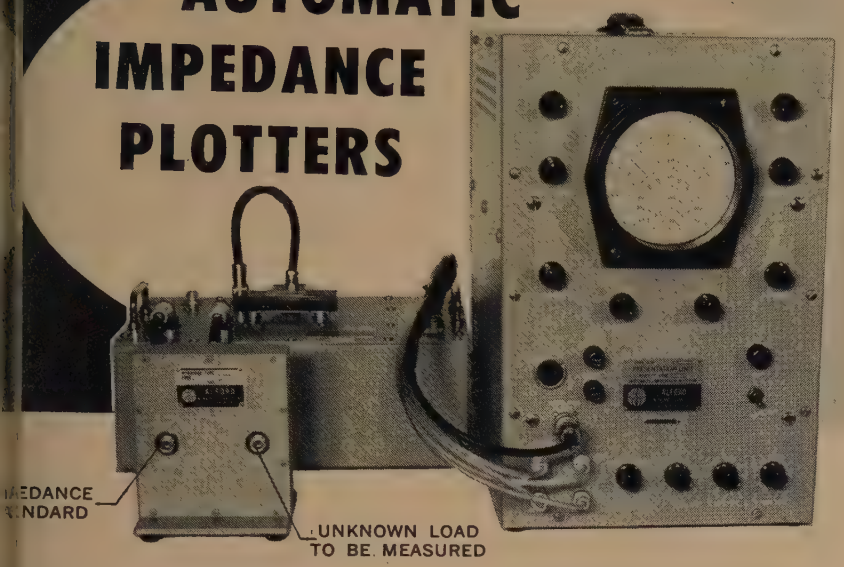
— *mwj* —

LONG-RANGE MISSILE TRACKING BARRIER BROKEN

A major breakthrough in long-range missile and space vehicle tracking through the use of the industry's first all solid-state, 440-mc beacon transponder system was announced today by W. F. Joy, vice-president in charge of Apparatus division, of Texas Instruments Inc.

Installed in an Air Force Thor-A Missile on September 17th, the beacon transponder system responded from 1 miles in space to an MIT Lincoln Laboratories Millstone Radar which tracked the missile from horizon to horizon during 14 minutes of its flight. This mark

NEW TYPE 14
AUTOMATIC IMPEDANCE PLOTTERS



Presents effectively continuous impedance information over a frequency band.
Entirely self-contained except for the use of an external oscillator.
Models available to cover 2.5-250 mc, 30-400 mc and 180-1100 mc.

Write for complete information on AMCI Automatic Impedance Plotter

AMCI ANTENNA SYSTEMS — COMPONENTS — AIR NAVIGATION AIDS — INSTRUMENTS
ALFORD Manufacturing Company
299 ATLANTIC AVE., BOSTON, MASS.

Circle Reader Service Card 35

First time that the Millstone has been successfully beyond skin-tracking ...es — a feat that made the test firing ...able despite third stage ignition ...ble which prevented the missile from ...ving an orbit, Mr. Joyce said. He ...d that the Millstone Radar-beacon ...ponder combination is capable of ...ing distances much greater than the ... miles achieved in the September ... attempt.

...sed on range information deduced ... the transponder's signals, person... from MIT's Lincoln Laboratories at Millstone site near Boston, Massachu..., were able to predict the missile's ... trajectory early in flight without ...usual wait for final accumulation and ...essing of all data from down-range ...cing stations.

...e battery-powered, solid-state trans...der system was developed, built, ...d and delivered in two and one-half ...ths to Douglas Aircraft, prime con...or for the Thor-Able, by Apparatus ...ion of Texas Instruments. It rep...nts the first in a series of very re..., ultra high frequency, solid-state ...on transponder systems that Appar... division plans to develop for com...ication links in deep-space probe ...ile shots.

...he new system is capable of 40 hours ...inuous operation on self-contained batteries, weighs only 6.3 pounds, and occupies only 0.058 cubic feet. A key factor in designing the system was the development by Texas Instruments of a new series of uhf transistors which made possible complete miniaturization of the transponder. Until now, transponders were designed with vacuum tubes which made them less practical for space applications because of larger size, heavier weight and greater power needs.

— *mwj* —

DAVID INGALLS RESIGNS AS AIRTRON PRESIDENT

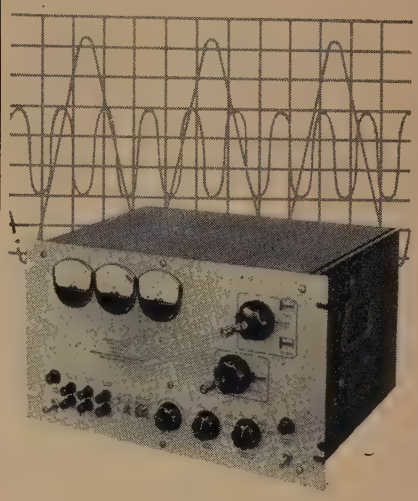
Effective December 1, 1959 David Ingalls announced his resignation as President of Airtron, Inc., Division of Litton Industries.

Mr. Ingalls founded Airtron in 1946, manufacturer of Radar and Microwave Electronic Equipment. The organization grew under his leadership to a ten-million-dollar-a-year business. In 1958 it became a wholly owned division of Litton Industries, and Mr. Ingalls became vice-president of the organization continuing as president and chief executive of Airtron, Inc.

Mr. Ingalls gave his reasons for leaving at this time as personal and disclosed no plans for the future except to do some extensive traveling before returning to active business life.

— *mwj* —

WIDE RANGE POWER OSCILLATOR



a reliable signal source for microwave measurement

The AIL Type 124C Power Oscillator is applicable as a signal source over the wide range of 200 to 2500 Mc. Its range, power and stability make it an essential element of microwave component test systems. It is often used in measurements relating to antenna design. Facilities for both internal and external modulation are provided. Relative power output is indicated directly on panel meter.

Detailed literature is available on request.

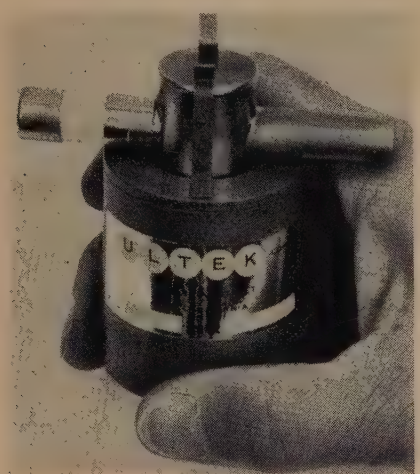
AIRBORNE INSTRUMENTS LABORATORY
1345 NEW YORK AVENUE
HUNTINGTON STATION, L. I., N. Y.
A DIVISION OF CUTLER-HAMMER, INC.

Circle Reader Service Card 36

New Products

ELECTRONIC HIGH-VACUUM PUMPS

The New Series 110 UlteVac Electronic High-Vacuum Pumps developed by the Ultek Corp., Palo Alto, Calif., are designed for use as permanent appendages on large electron tubes, and are also suitable for miscellaneous types of industrial and laboratory applications, such as maintaining high vacuum in vacuum-jacketed vessels. They are used on microwave tubes, storage tubes, display tubes, x-ray tubes, and other special-purpose devices to extend cathode life by removing micro amounts of gas liberated during operation.



Pumping 0.7 liter per second, units in the 110 Series are small in size, compact, and light in weight. Pump unit and accompanying magnet together weigh 1.6 pounds, and the magnet is 2 inches o-d.

Having a cold-cathode discharge and a body fabricated of stainless steel, UlteVac Pumps are engineered for long operating life.

Four standard configurations are offered to facilitate integration into tube design. Two of these are arranged so that the tube is evacuated directly through the UlteVac unit so that no separate tube exhaust is required. Other configurations can be supplied, and various exhaust tubulations can be provided to meet individual needs.

In operation, the UlteVac Pump draws current in a linear relationship with pressure. This permits the pump to double as a vacuum guage.

Circle Reader Service Card 101

— *mwj* —

PARAMETRIC AMPLIFIER FOR 100-220 MC RANGE

A low noise regenerative parametric amplifier assembly for the 100-220 mc frequency range is available from Microwave Associates, Inc. of Burlington, Mass.

Model MA-1-150 exhibits receiver noise figure below 2 db (maximum) over the specified tuning range when used together with a good low noise receiver of 6-8 db noise figure. The MA-1-150 circuit is designed to provide flexibility of operation and general experimental versatility. It is particularly useful in demonstrating the parametric amplification regenerative principle or in breadboard receiver design applications.

The amplifier consists of a single stage coaxial resonant cavity 16 1/2 inches high by 4 inches in diameter with tuning controls provided for resonating signal and idler with injected RF pump power. A suitable Varactor diode and spare are supplied with each amplifier. The amplifier is available complete with suitable pump oscillator, power supply and interconnecting cables and fittings.

The amplifier cavity is silver plated. External metal surfaces are coated with blue-gray lacquer.

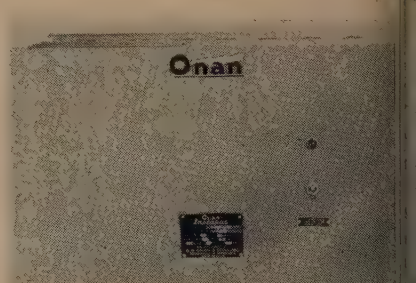
The MA-1-150 is one of a series of three new amplifiers offered by Microwave Associates tuning the 100-500 mc frequency range.

Circle Reader Service Card 10

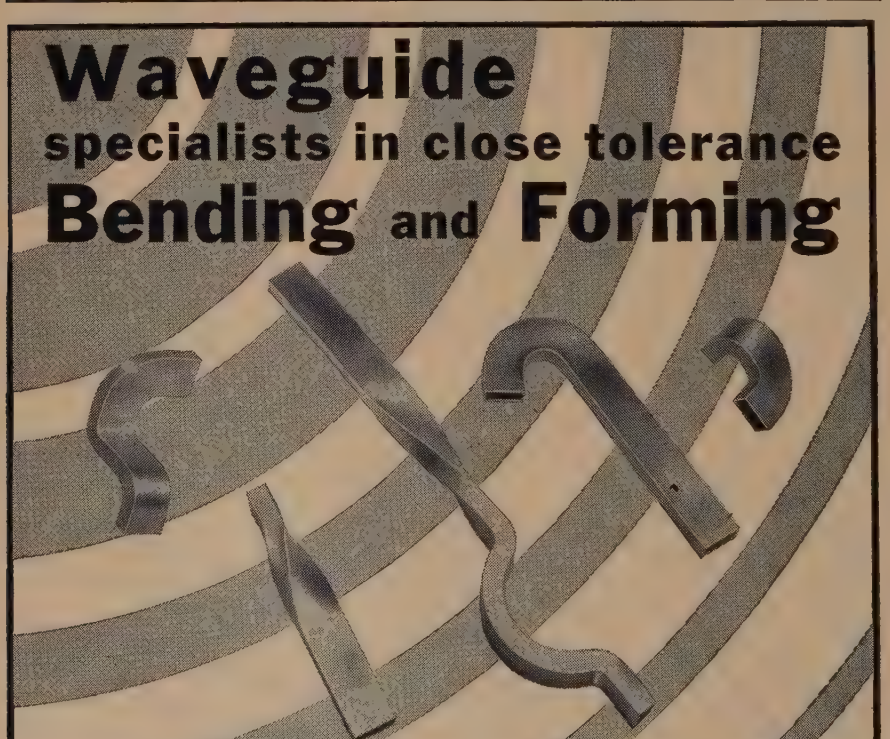
— *mwj* —

ONAN INSTAPAC TRANSISTOR INVERTER POWER UNIT

INSTAPAC is an Onan-developed transistorized inverter power unit, which will instantly supply adequate A.C. power to the load (e.g. microwave radio equipment, electronic timers, hospital lights etc.) on interruption of commercial power. INSTAPAC effectively bridges the inevitable few seconds gap of power loss which occurs between the time commercial power is interrupted and before the engine-driven standby electric plant can start, come up to required speed and voltage, and take over the load.



The new Onan INSTAPAC power unit will take over any load, within its power range, in about 25 milliseconds. When there is an interruption in commercial power, a fast-acting relay switches the load from this power line to the DC inverter. As this is occurring, the engine-driven standby plant starts and takes over the load. When normal power returns, the standby generator stops and the Onan INSTAPAC again supplies power for the short time required for the automatic line trans-



Circle Reader Service Card 37

...h to return the load back to com-...al power.

...in components of the Onan INSTA-... include a transistorized inverter, ...transfer relay, start-stop relay, test ...h and indicator light mounted on ...' rack panel. Batteries, while re-...d, are not included as part of the ...ter. For normal installation, stand-... automotive-type, 12-volt batteries, ...cted in series to provide 24, 36, ...-volt, D.C. input to the INSTAPAC ... can be used. Continuous operation ...d only by the capacity of input ...r.

...tional accessories include battery ...ers; special relays and timers; ...s; batteries; wall mount cabinet. ...though the Onan INSTAPAC is de-...d specifically to operate in conjunc-... with an Onan Emergency Electric ... and an Onan Automatic Line Trans-...Control, it is adaptable to existing ... by equipment with minor changes ...viring. Little maintenance is re-...d for the Onan INSTAPAC because ...s no moving parts or adjustments. ...ce INSTAPAC is not normally con-...d between the power line and load, ... therefore does not in itself add ...ponents to the line (which in turn ...cause a failure) this effective system ...ides the maximum in power supply ...ection.

...rcle Reader Service Card 103

— *mwj* —

... PRECISION WAVEMETERS

... line of secondary-standard, broad-... wavemeters equipped with large ...ometer heads is announced by De-...hay-Bonardi, Pasadena, California.

...welve models, each covering an en-... waveguide bandwidth, cover the ...e 2.6-140 KMC. The units are high-...nd pressurized with an inert gas. The ...uments are unaffected by changes in ...idity, altitude, or barometric pres-... Individually calibrated, each in-...ment is supplied with a multiple page ...bration chart.

...he wavemeters are described in Bul-...n D-B 715 which is available on ...uest.

...ircle Reader Service Card 104

— *mwj* —

...50° C TRIPOLAR VIDEO DIODE

...Microwave Associates, Inc. of Burling-... Mass. announces availability of the ...530 broadband tripolar coaxial diode. ... 1N630 is rated for use over the tem-...ature range — 40° C to + 150° C. This diode is a direct replacement for the 1N358 tripolar diode in microwave video receivers used in video detection applications in the 1 kmc to 12.4 kmc frequency range.

The 1N630 input impedance of 65 ohms is matched to standard 50 ohm coaxial lines using holders such as the Sage Lab. Model No. 101 which incorporate suitable matched coaxial transitions.

The 1N630 minimum figure of merit is 15. Video impedance is 4500-18000 ohms. Tangential signal sensitivity is — 40 dbm (min.).

Circle Reader Service Card 105

— *mwj* —

BAND REJECTION FILTER

A compact microwave filter which passes a specific frequency band while sharply rejecting other frequencies above the pass band is announced by Airtron, Inc., a Division of Litton Industries, Morris Plains, New Jersey.

Initial designs constructed are for C-band operation, but Airtron reports they can be developed for any waveguide size or frequency range from 3,000 to 36,000 Mc, and for larger or smaller pass and stop bands. The unit consists of a straight section of waveguide with four E-plane cutoff stub arms located along one broad wall of the waveguide. Higher rejection in the stop band is obtained by employing additional stub sections.

Stub sections are properly proportioned to yield a certain value of cutoff frequency; stub lengths are chosen so as to be resonant within the rejection band and are stagger-tuned so the rejection band is of the desired width. Microwave energy at frequencies below the stub cutoff frequencies is transmitted through the guide with minimum loss, since each stub appears as a small reactive element in series with the waveguide. Stubs are so spaced that reactances are almost completely cancelled within the pass band, and the filter yields a pass band with negligible loss and small mismatch.

Typical Electrical Characteristics at C-Band are: insertion loss in the pass band of 0.3 db max.; VSWR in the pass band is 1.40 max.; rejection in the stop band is 30 db min., and the power handling capacity of the unit is 0.5 Megawatt C.W.

Circle Reader Service Card 106

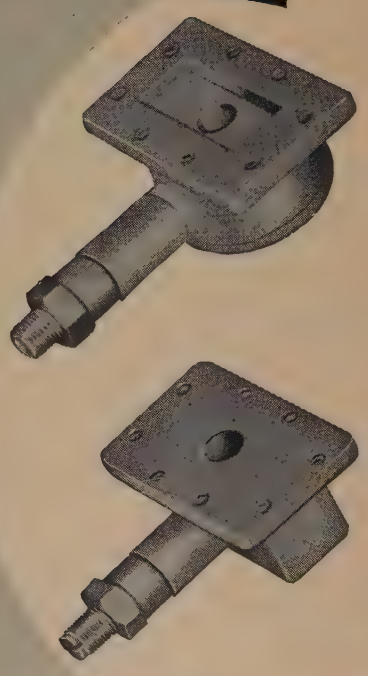
MICROWAVE CAVITIES

NEW

Here is a cavity, designed for microwave link application, which replaces a unit costing four times as much. Shown are glass seal tunable cavities for use with microwave discriminators. Some of their outstanding characteristics are:

1. Tuning range 5925-6425 mc
   6575-6875 mc
   7125-7750 mc
2. Temperature stability ± 2 mc for — 20° to +70°C.
3. No change with humidity.
4. Can withstand severe vibration and shock.
5. Loaded Q = 250.

This unit along with its accompanying discriminator, can be made available in all waveguide sizes from L through Ka band.

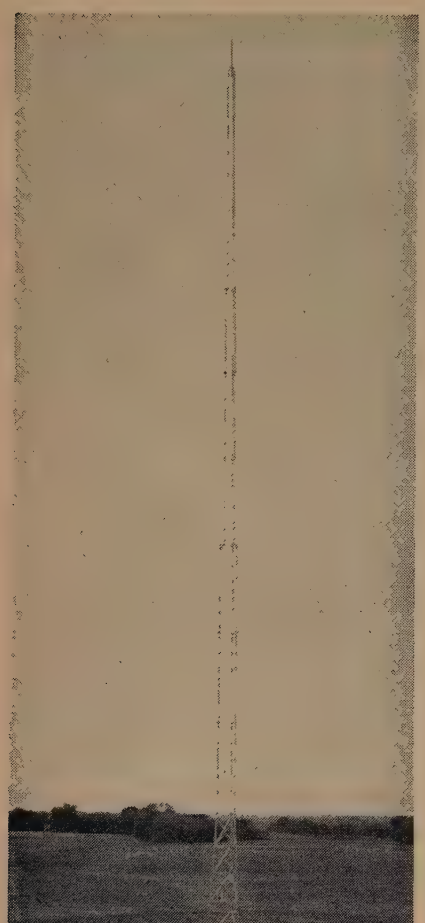


PORTCHESTER INSTRUMENT CORP.

114 WILKINS AVE. PORTCHESTER, N.Y.

Circle Reader Service Card 38

New ROHN
SELF SUPPORTING
COMMUNICATION TOWER



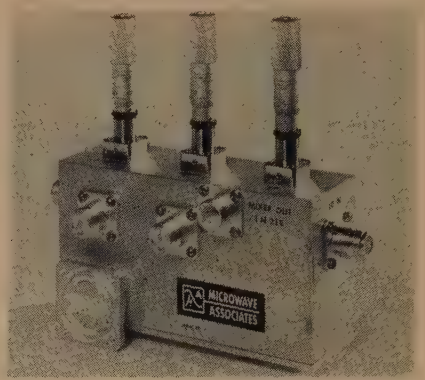
★ 130 ft. in height, fully self-supporting!
★ Rated a true HEAVY-DUTY steel tower, suitable for communication purposes, such as radio, telephone, broadcasting, etc.
★ Complete hot-dipped galvanizing after fabrication.
★ Low in cost—does your job with BIG savings—yet has excellent construction and unexcelled design! Easily shipped and quickly installed.

FREE *details gladly sent on request. Representatives coast-to-coast.*

ROHN *Manufacturing Co.*
116 Limestone, Bellevue, Peoria, Illinois

"Pioneer Manufacturers of Towers of All Kinds"

NEW L-BAND PARAMETRIC AMPLIFIERS IN 950-1350 MC RANGE AVAILABLE



Microwave Associates, Inc., Burlington, Mass. announces availability of two new Parametric Amplifier mixer, down-converter units for very low noise signal reception.

Model MA 2-1000 is used for the 950-1250 Mc frequency range and a second model, MA 2-1000L is designed for use in radar receivers in the 1250-1350 Mc range.

Both models exhibit noise figures below 2 db with bandwidth of 1/4 percent. Image rejection is better than 50 db down, and dynamic range is 80 db or better.

The amplifiers comprise a single stage of parametric preamplification using a suitable Varactor diode, a low noise mixer, down-converter stage with a 1N21E or MA-421B (1N21F) diode, and a third stage for convenient coupling of the injected local Oscillator RF input. The basic amplifier chassis dimensions are 6" long x 3" wide x 2" high.

A BNC type cable couples the mixer output to I.F. amplifier input stage of receivers with which the units are to be used. L.O. and signal input are by means of type "N" fittings. The chassis is silver-plated brass. Precision micrometer drive controls facilitate accurate tuning adjustment. A calibration chart is supplied with each unit.

Complete MA-2 amplifiers consist of the basic unit, pump oscillator, power supply and waveguide accessories.

A Radar range improvement of 30-50% has been reported as a result of field tests with the amplifier.

Specifications are available on request.

Circle Reader Service Card 107

— *mwj* —

LOW NOISE SILICON MIXER DIODE FOR USE FROM 100-4000 MC (E.I.A. TYPE)

The 1N21F very low noise silicon microwave mixer diode for superheterodyne receiver use at frequencies from 100-4000 mc is available from Microwave Associates.

The 1N21F calculated overall receiver noise figure is 6.0 db maximum measu with a 1.5 db 30 mc IF amplifier.

VSWR is 1.3 (max.) and IF impeda limits are 350-450 ohms. Reversed pola 1N21RF and matched pair 1N21FM a 1N21FMR diodes are also available.

The 1N21F supercedes the 1N21C 1N21E in applications which require h signal to noise performance.

The diode has immediate applicati in low noise mixers following parame preamplifier stages, VHF/UHF sca communications and navigational receiv and permits design of all solid-state receivers for very low noise signal rec tion at these frequencies.

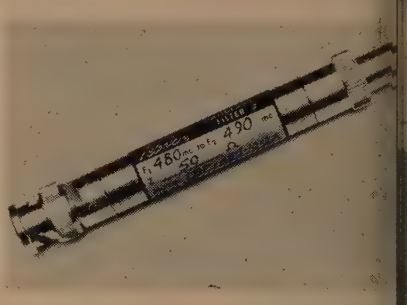
The 1N21F is available in product quantities. Detailed information is av able.

Circle Reader Service Card 10

— *mwj* —

NEW MINIATURE COAXIAL BAND PASS FILTERS FOR MISSILE APPLICATIONS

Miniature band pass filters designed s cifically for aircraft and missile appl tions are now available from Telonic E neering Corp., Laguna Beach, Californi



The new Telonic TBP filters cover frequency range from 200 mc to 2400 Bandpass may be set at any value betw 5% and 25%. The number of sections n be varied from 2 to 4, with an insert loss of .5 ± .2 db per section. The e trical performance of the filters corresp to resonant cavities or tank circuits hav unloaded Q's of over 200.

A feature of the new Telonic TPB Fil is their small size. Diameter of the u is only slightly over that of the BNC c nectors at each end (units with o standard connectors are also available). lumped-constant filter design is used, w capacitance obtained by using close-to ance machined teflon and silver-plated b parts. Special temperature resistant forms and spacers insure a high degree mechanical stability and permit opera at temperatures higher than 100°C.

The small size and rugged design of Telonic TBP Filters make them ide suited to missile and aircraft applicati They are capable of withstanding all the principle environmental stresses countered in equipment designed for use, including shock, vibration, tempera cycling and high G forces.

Circle Reader Service Card 1

WAVEGUIDE TERMINATION SPEARS

e Radar Design Corporation of Syra- N.Y. announces that it has expanded ine of waveguide terminating spears ver waveguide sizes ½" x ¼" through " x 4.46".

tapped mounting hole is provided in base of the spears by which they may adily incorporated into waveguide cir- y.

he VSWR for any spear is 1.02 or less its applicable waveguide frequency range. Made of "Radite 75," the spears provide terminations for low and medium power applications.

A series of bulletins which show performance, applications, detailed dimensions, and material characteristics are available upon request.

Circle Reader Service Card 110

— *mwj* —

FOTOCERAM GRID BOARD

Electronic designers can now make, and remake, their own high quality printed circuit layouts — without leaving their labs — with a new product made by Corning Electronic Components.

It is a Fotoceram grid board, designed by Corning as a valuable tool for prototype work. It is clad on both sides with copper that can be etched away as desired. The grid for installation of components consists of .052-inch round holes spaced 1/10-inch apart on center.

No special equipment is needed to use the board, according to the Electronic Components Department of Corning Glass Works.

The boards are 1/16-inch thick. They are available in three sizes: 3 x 5, 6 x 8 an 9 x 12 inches.

Fotoceram is a glass-ceramic developed by Corning. It has high strength, high temperature resistance, zero water absorption, and is non-flammable and dimensionally stable.

Circle Reader Service Card 111

PRECISION WAVEGUIDE BENDING

TO YOUR SPECIFICATIONS

Bends, Twists, Offsets, Coils, Transitions, Fabrications and complete assemblies to your prints.

Specialty

AUTOMATIC MACHINE CORPORATION

80 CAMBRIDGE ST.
BURLINGTON, MASS.
TEL: BRowning 2-0800

Circle Reader Service Card 40

for

ACCURACY

and

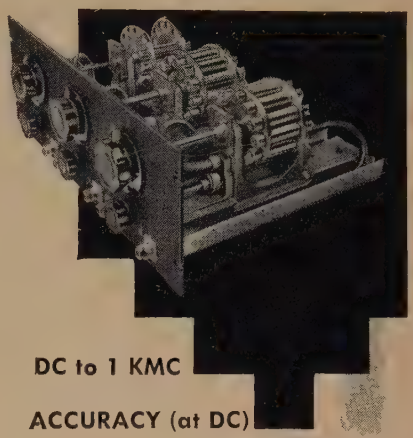
STABILITY

WEINSCHEL

PRECISION COAXIAL

S——————
T——————
E——————
P————

ATTENUATORS



DC to 1 KMC

ACCURACY (at DC)

1 to 5 db: .02 db
6 to 10 db: .05 db
20 to 50 db: .10 db

RF CALIBRATION ACCURACY

1 to 30 db: .1 db
40 to 50 db: .2 db

We supply **individual calibrations** at 400 and 1000 MC and, upon request, at other frequencies.

ATTENUATION RANGE

MODEL 60
2 drums, 0-60 db in 1 db steps

MODEL 64
3 drums, 0-64 db in .1 db steps

MODEL 640
3 drums, 0-110 db in 1 db steps

Impedance-50 ohms
Connectors-Female Type N

Long term repeatability and **assured quality** are a result of our **experience** in making coaxial attenuators with our own stable film resistors **since 1947.** Our facilities for **attenuator calibration** are the **most accurate facilities** available commercially.

Weinschel Fixed Coaxial Attenuators cover the **frequency range of DC to 12 KMC.**

WE CO

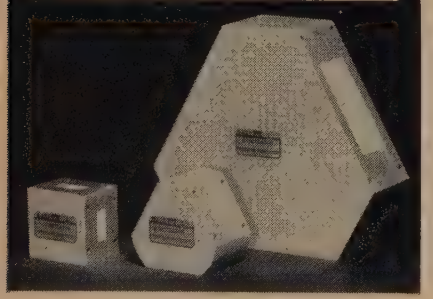
Write for complete catalog, specifying frequency range of interest.

Weinschel Engineering
KENSINGTON, MARYLAND

Circle Reader Service Card 41

CASCADE RESEARCH has designed and manufactures a series of new Y, T and Cross-type circulators— *one-tenth to one-fifth the size* of conventional types. Especially suited for maser and parametric amplifier applications where minimum size and weight are essential.

AVAILABLE IN THESE BANDS:
S - G - J - X L - X - K



GENERAL SPECIFICATIONS

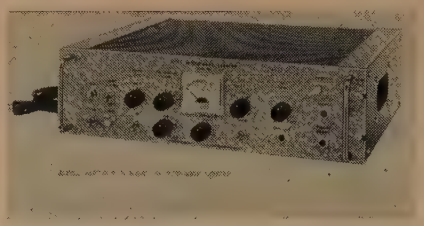
Peak Power	100 K.W.
Average Power	100 watts
Maximum Insertion Loss	0.5 db
Minimum Isolation	20 db
Maximum V.S.W.R.	1.2
Frequency Band	5% or more

MONOGRAM PRECISION INDUSTRIES INC.

CASCADE RESEARCH DIVISION
5245 San Fernando Road-West / L. A. 39 / California / CHapman 5-8625

Circle Reader Service Card 42

ALFRED INTRODUCES NEW LEVELER AMPLIFIER



A new broadband dc leveler amplifier featuring extremely high gain is now available from Alfred Electronics, Inc., Palo Alto, California manufacturer of broad band microwave instruments and power supplies.

Used with an external crystal detector and directional coupler, Alfred's Model 700 Leveler Amplifier can hold r-f output from single frequency or swept microwave sources constant to $\pm$ .1 db at a fixed frequency.

Because of the high amplifier gain (6 x 10^6), variations with frequency are entirely a function of the crystal-coupler characteristics. With proper r-f components, power varies less than $\pm$ ½ db over L, S, C and X bands at slow and fast sweep speeds.

The Leveler Amplifier is also a broadband attenuator with a 30 db dynamic range over which output power is constant. Model 700 operates with CW signals and an internal square wave generator will modulate the r-f signal.

Input may be 3 mv to 1 volt. Output is 100 volts maximum in the range of — 50 to + 100 volts. Frequency response is dc to 100 kc.

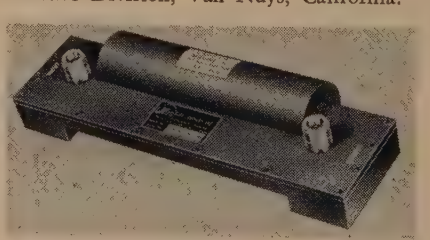
For use with microwave tubes that are operated with the control electrode at a negative potential, a floating output with 5 kv insulation is provided. Gain is 5 x 10^6 and frequency response is dc to 50 kc with output voltage of 450 v maximum.

Circle Reader Service Card 112

— *mwj* —

NEW OCTAVE S-BAND FERRITE ISOLATOR

A new S-band ferrite isolator spanning a full octave in frequency range has been developed by Kearfott Company, Inc., Microwave Division, Van Nuys, California.



Incorporating new ferrite and waveguide techniques, the Model WD-2106 Octave S-band Isolator is an outstanding advancement in the microwave field. Its very wide bandwidth permits the use of only one isolator for a full octave, and eliminates the necessity of covering the band in increments with the use of a number o isolators.

The new isolator's characteristics are a follows: Frequency range: 2.1 to 4.3 kmc Isolation: 20 db minimum; Insertion loss 2 db maximum; Input VSWR: 1.5 maximum; Peak power: 1.0 kw maximum average power: 5.0 watts maximum; tem perature ambient: 65° maximum.

Further information on the Model WD 2106 is available on request.

Circle Reader Service Card 113

— *mwj* —

NEW MICROWAVE FILTER LINE INTRODUCED

A new standard line of high and low pass microwave filters is now availabl from Frequency Standards, Asbury Park New Jersey.

The units, designed for high perfor ance, small size and reduced weight, ha a peak power handling capacity up to 2 kw

The low-pass filters are 13 element net works and are available in 1 db down fr quencies of 500, 1200, 2300, 3100, an 6000 mcs. The high-pass filters are 7 ele ment networks available in 1 db down fr quencies of 400, 900, 2000, 2700, an 5400 mcs.

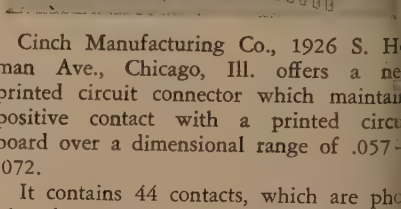
Both the low and high-pass filters hav a maximum insertion loss of 0.5 db in th pass band. The input VSWR is 1.5:1 o less below the 0.1 db down point for low pass filters and above the 0.1 db down poin for high-pass filters.

All units are furnished with Type N r connectors.

Circle Reader Service Card 114

— *mwj* —

NEW PRINTED CIRCUIT CONNECTOR WITH WIRE WRAP TERMINATION



Cinch Manufacturing Co., 1926 S. Hi man Ave., Chicago, Ill. offers a ne printed circuit connector which maintain positive contact with a printed circu board over a dimensional range of .057 - .072.

It contains 44 contacts, which are pho phor bronze with a silver plate of .000 and .00003 gold plate finish. The co number is 29401.

A plastic polarizing key is furnishe with each connector, and this key can inserted into the contact slot of any co tact position. The inventory problem simplified by providing a single connect that can be polarized in any position.

Circle Reader Service Card 115

— *mwj* —

ANTENNA PATTERN TOWER

new fiberglass antenna pattern tower swings heavy models from a 25′ down to ground level for servicing just been announced by Blaine Electics, of Van Nuys, California, de-

rs and manufacturers of this equip- Dubbed "Project TEETER-TOT-" reflecting the unusual 22′ truss which actually operates like a giant w or balanced beam capable of swingweights on the order of a ton, this was designed to fit a growing need essed by many antenna design and test neers in this country and abroad.

e requirements of Lockheed Aircraft oration, California Division, Radar and nna Research Group under Mr. T. W. rock, guided the original design and opment of the equipment, and appli- n of Blaine Electronetics techniques, ed in several years of building antenna tion pattern measurement equipment, ed economical and efficient production. esignated Blaine Model 14/T6, this heavy duty fiberglass tower, essen- "transparent" to radio, is designed upport or position not only mock-ups, els and missiles up to 500 lbs, in ht, but also two-axis azimuth/elevation ioners which themselves may weigh e quarter of a ton.

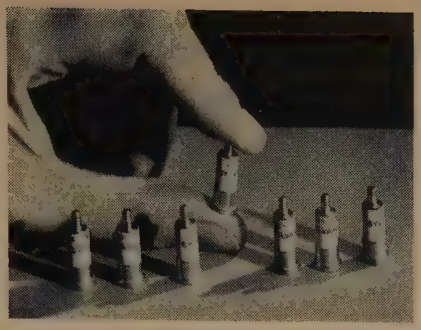
very rugged steel base platform, twelve square, on four heavy duty swiveling rs forms the frame from which rise extremely stable pyramids made of glass tubing at the top of which are ings for the shaft-axle which is five es in diameter. The beam itself is four square in section and its members are ial high glass content reinforced plastic s, exceedingly strong and rigid and mbling a welded tubular steel structure ppearance. The use of fiberglass rein- ed plastic tubes as primary and second- structure assures virtually no pattern rference.

ircle Reader Service Card 116

— mwj —

NEW SYLVANIA MICROWAVE MIXER DIODE FOR RADAR AND MISSILE TRACKING SYSTEMS

Sylvania Electric Products Inc. has anced a new L-band silicon microwave de which it says will increase substanly the performance and range of radar



and missile tracking systems, and similar electronic equipment. Sylvania is a subsidiary of General Telephone & Electronics Corporation.

Roger A. Swanson, product sales manager — microwave diodes of Sylvania's Semiconductor Division, said that the new diode is designed for microwave mixer applications in the L-band frequency spectrum. This covers the top of UHF range to 1500 mc.

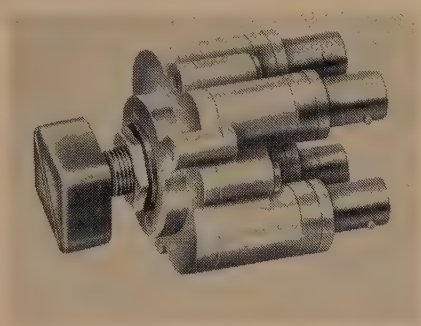
Designated the D-4097, the new Sylvania diode is a point contact type. It exhibits a maximum conversion loss of only 5.5 db with a maximum output noise ratio as low as 1.5 times. This is the equivalent of a 2 db improvement in noise figure for a receiver whose IF amplifier noise figure would be 1.5 db, or a 13 percent increase in range.

Circle Reader Service Card 117

— mwj —

RUGGED NEW COAXIAL SWITCH

A new manually-operated rotary coaxial switch has been placed in production by Jerrold Electronics Corporation, Philadelphia. Designed for use wherever r-f en-



ergy is to be switched from one circuit to another, the new CS-250 transfers r-f energy from 0 to 1000 mc with a maximum VSWR of 1.1 up to 500 mc and 1.2 up to 1000 mc.

The ruggedly-built CS-250 is a four terminal, two position transfer switch, coaxially mounted in a rugged die cast metal frame. Its dull wiping, self-aligning switch contacts are silver, mounted in a Kel-F dielectric.

Insertion loss in the CS-250 is less than 1/10 db to 1000 mc. Isolation between the open and closed circuit is 58 db at 100 mc and 40 db at 1000 mc.

The CS-250 is available with BNC connectors at 50 ohm impedance.

The new switch will sell for $19.60.

Circle Reader Service Card 118

— mwj —

Aluminum wave guide components, large and small, are cast smooth, sound and accurate by the unusual foundry methods of Morris Bean & Company, Yellow Springs 5, Ohio

BEAN

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magnesium
ductile iron
foundries

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Wherever you are carrying on scientific investigations, we doubt if you can call on advanced facilities and complementary scientific skills equal to those available at the Research Laboratories.

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The Research Laboratories are organized to respect the time and abilities of men working in advanced scientific areas. If you appreciate an environment where a scientist can focus full mental power on scientific accomplishment, we would like to hear from you.

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Energy Conversion
Instrumentation
Electrical Propulsion

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FREQUENCY STANDARDS

Asbury Park, New Jersey

BOX SCORE

NAME: Frequency Standards, a Division of Harvard Industries, Inc.

LOCATION: Asbury Park, New Jersey.

PRODUCTS: Low and high pass filters, broad band filters, band reject filters, direct-reading wavemeters, oscillator and amplifier cavities, microwave discriminator and frequency control systems, mixers and video detectors, custom designed r-f components for use in measurement, control and test at microwave frequencies, gang-tuned pre-selectors.

HIGHLIGHTS: Bringing to the microwave industry long experience in precision machine work, Frequency Standards has moved from development and prototype work into the area of providing a well-rounded product line. Anticipating growing market demands, Frequency Standards management continually works to expand its product mix.

STATISTICS: Frequency Standards sales in 1958 ran just over a million dollars; in 1959 volume was slightly under two million dollars. For 1960 anticipated volume is two and a half millions, and by 1962 the company expects a volume of five millions.

When a long-established precision machining company in Asbury Park, New Jersey, began manufacture of a proprietary micrometer thread in 1949, its intention was to fill in idle machine time. Unexpectedly, the company discovered a dynamic new market for its product — and apparently for other finely machined components it had proven itself capable of producing.

The majority of orders for the micrometer thread came from microwave manufacturers who wanted it for positioning cavities and similar devices. Having already made frequency meters for Federal Tel. & Radio, the company had confidence that it could enter the electronics field, specifically microwaves, on the strength of its machining skills.

To handle micrometer thread sales, a paper organization called Frequency Standards had been established. Once management realized the potential in microwave business, Frequency Standards was furnished with a number of standard designs for precision frequency meters. Produced on the parent company's machines, the meters proved to be more accurate than most similar units then available. (FS direct reading frequency meters provide an absolute accuracy of .01 percent.)

Frequency's superior meters stimulated a flow of requests for development and production of special frequency meters, cavities, and filters, an area in which Frequency Standards has demonstrated its leadership for the past seven years. Reflecting the enormous variety of electronic systems under development during the 50s, Frequency Standards accumulated 400 specialized meter

Frequency Standards plant, Asbury Park, New Jersey.

FS top management holds product conference. General Manager Ellis Slack (coat) discusses a direct reading precision wavemeter with (left to right) John Wallace, Controller; John Vogler, Chief Engineer; Russell McCorkle, Plant Manager; Gino DePaola, Assistant Chief Engineer, and Harry Dolan, Sales Manager.

and filter designs from 1954 to 1959. These are now available to customers who can cut their lead time and development costs by selecting or modifying the existing designs which fulfill their requirements.

Recognition of FS's rapidly developing reputation in the microwave field resulted in the decision to give the organization operating status in 1952. With a staff of four, including John Vogler, present chief engineer, the new company began production utilizing the same precision machining facility from which it had grown. By 1953 employment reached 15; in 1956 the number was up to 35.

A dramatic turnabout occurred late in 1957 when the parent company dropped its own name in favor of designating the entire operation Frequency Standards. In February, 1959, Harvard Industries, Inc., headquartered in Pittsburgh, acquired FS as a division among its group of diversified companies. Since Frequency's changeover from private to corporate ownership, it has boosted employment to approximately 145 and expanded to 20,000 square feet of plant space.

Soon, Frequency Standards became known primarily as a development service organization, capable of meeting unusual requirements. While undertaking assignments which advanced the state of the art and provided invaluable engineering experience for its staff, FS eventually found itself going into production on only a small percentage of the items developed.

Products

Product diversification is one of the first steps the new management is taking to insure FS's growth. Now being added to the established line of band-pass filters, preselectors and wavemeters are:

- — Low and high pass filters.
- — An extended line of precision direct reading wavemeters.
- — Broad band filters.
- — Oscillator and amplifier cavities.
- — Microwave discriminators and frequency contr systems.
- — Mixers and video detectors as well as combin tions of mixers and video detectors with tunab pre-selectors.
- — A line of band reject filters.

Chief Engineer Vogler calls the above a logical versification based on FS's past experience. "Since have always supported our own development work," says, "we have been able to maintain a great degree independence, and consequently we have not been stricted to any specific area."

Vogler cites gang-tuned pre-selectors as representi Frequency's unique product philosophy — and over ha its business.

"We're the only company offering a standard line gang-tuned pre-selectors," he explains, "because othe find them too difficult to make in any quantity. O units are distinctive because of the precision with wh the shop meets Engineering's specifications."

FS developed its gang-tuned pre-selector as a mecha ical coupling of tuning elements of up to four in vidual cavities. The design also provides for adjustme of the electrical parameters of individual cavities maintain uniform response characteristics over wi tuning ranges when tuning is accomplished with a sin control.

In addition, FS offers a combination of gang-tu pre-selectors and video detectors or mixers. This gi the customer a guaranteed package performance rat than only an individual component guarantee.

Among major projects for which Frequency Standa

Operator uses optical attachment on precision jig bore.

eveloped and supplied various components are: e guidance and pre-flight checkout systems; AN ground beacon, and microwave feeder links rans-continental relay links made by Western Elec- or Bell Telephone.

nong its major customers, Frequency Standards Bendix Aviation Corp.; Boeing Airplane Co.; ir Division, General Dynamics Corp.; General ic Co.; Hughes Aircraft Co.; Motorola, Inc.; Ray- Co.; Sperry; RCA; Stromberg-Carlson Co.; West- lectric Co.; Westinghouse Electric Corp.

rties

a result of its highly specialized development ac- , FS is today equipped with one of the finest wave test laboratories in the country. Prominent s air-conditioned facility is a frequency monitoring n to allow calibration of secondary frequency ards against WWV, National Bureau of Standards station. Other equipment includes a complete line veep generators and environmental test facilities eck component performance under MIL-spec. The atory also measures frequency, attenuation, noise e, and phase.

closer tolerances and higher frequencies have been fied with accelerated advancements in the state of rt, FS has attempted to keep improving the already quality of its machining operation. Russell Mc- le, Plant Manager, and, like General Manager Slack, ned to Asbury Park from Pittsburgh, describes equipment as equivalent to that found in a precision shop with the addition of production machinery. ch features as optics and air conditioning are ard on FS precision machinery. "We try to obtain best and most up-to-date equipment available," s McCorkle, "in order to be able to do what Engi- ng asks."

le

eryone on Frequency's staff of 16 engineers is a alist and has had direct experience in the micro-

General view of FS Engineering Department.

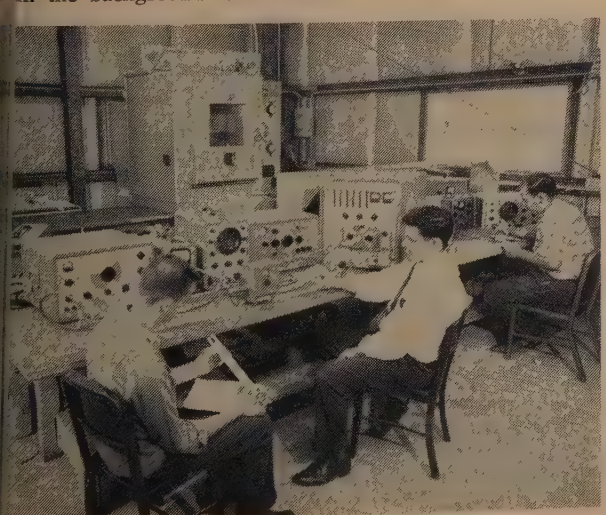
wave component field. In addition, several of the engineers have had substantial experience in design and production of microwave systems. Three engineers are antenna experts, a prime reason why FS is now seeking development contracts for antennas.

Russell McCorkle, Plant Manager, was appointed by Harvard Industries in February, 1959. A long-time resident of Pittsburgh, McCorkle was a senior industrial engineer with a firm of consulting industrial engineers before moving to Asbury Park. Earlier, he had been Chief Supervising Tool Engineer, Production Manager, Manager of Manufacturing, and finally Plant Manager for Miller Printing Machinery Company.

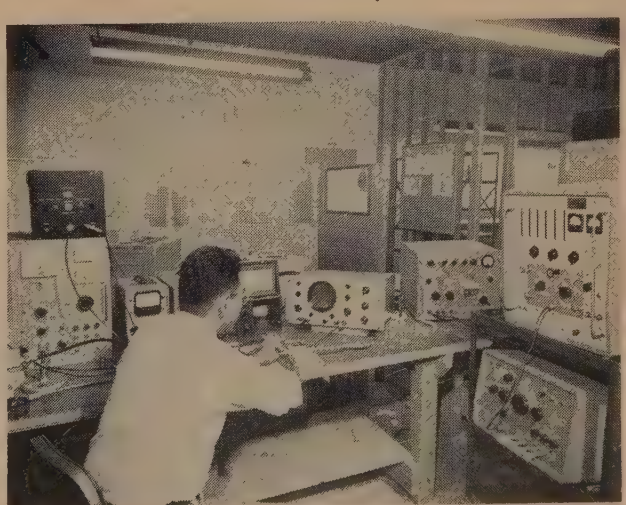
As a consulting design engineer, McCorkle designed special equipment for Collins & Wright, tableware manufacturers. He also was Chief Tool Designer for Kerotest Manufacturing Company, maker of valves and fittings for oil field use. McCorkle earned BS degrees in mechanical engineering, and industrial engineering.

Chief Engineer Vogler, who has participated in every Frequency Standards development since 1950 when he joined the original machining operation as a technician, anticipates a strengthening of his engineering staff as the product line increases.

in FS laboratory to test and adjust a gang-tuned X-band elector. In foreground, at left, is r-f sweep generator. In the background is an environmental test chamber.



Adjusting a four-cavity gang-tuned S-band pre-selector in the test laboratory.



Diamond can offer the solution to your rotary joint problems — waveguide or coaxial . . . high power . . . inline . . . broadband . . . multi-channel — whatever they may be.

WAVEGUIDE IN-LINE ROTARY JOINTS

DIC NO.	W.G. SIZE	FREQUENCY KMC/S	VSWR (Max)	INSERTION LOSS (Max)	"WOW" (Max)	POWER HANDLING Peak	Average
445*	3 × 1½	2.6–3.95	1.5 : 1	0.1 db	.05 db	370 KW	3 KW
545*	2 × 1	3.95–5.85	1.5 : 1	0.1 db	.05 db	160 KW	2 KW
645*	1½ × ¾	5.85–8.2	1.5 : 1	0.1 db	.05 db	73 KW	1 KW
845*	1 × ½	8.2–12.4	1.5 : 1	0.1 db	.05 db	37 KW	1 KW
945*	.702 × .391	12.4–18.0	1.5 : 1	0.1 db	.05 db	16 KW	1 KW
1045*	½ × ¼	18.0–26.5	1.5 : 1	0.1 db	.05 db	8 KW	½ KW
1145*	.360 × .220	26.5–40.0	1.5 : 1	0.1 db	.05 db	3 KW	½ KW

* Patents applied for.

SINGLE CHANNEL COAXIAL ROTARY JOINTS

DIC NO.	LINE SIZE	FREQUENCY MC/S	VSWR (Max)	INSERTION LOSS	"WOW" (Max)
2045	6⅛	100–140	1.15 : 1.0	Negligible	0.5 db
2046	6⅛ (75 ohm)	400–700	1.2 : 1.0	Negligible	.05 db
2047	3⅛	200–400	1.2 : 1.0	Negligible	.05 db
2048	3⅛	400–600	1.1 : 1.0	Negligible	.05 db
2049	⅞	400–450	1.1 : 1.0	Negligible	.05 db
2049-2	⅞ (46.5 ohm)	2170–2320	1.15 : 1.0	Negligible	.05 db
2049-3	Type N	200–300	1.5 : 1.0	Negligible	.05 db
2050	1⅜	2100–2400	1.15 : 1.0	Negligible	.05 db
2400-1	⅜	4–15 kmc /s	1.8 : 1.0	Negligible	.05 db

DUAL CHANNEL COAXIAL ROTARY JOINTS

DIC NO.	CHANNEL	LINE SIZE	FREQUENCY MC/S	VSWR (Max)	INSERTION LOSS	"WOW" (Max)
2246	Main Auxiliary	6⅛ 3⅛	380–440 380–440	1.15 : 1.0 1.2 : 1.0	Negligible Negligible	.05 db .05 db
2247	Main Auxiliary	6⅛ Type N	415–455 I.F.F.	1.15 : 1.0 1.2 : 1.0	Negligible Negligible	.05 db .05 db
2248	Main Auxiliary	3⅛ 3⅛	785–815 785–815	1.1 : 1.0 1.15 : 1.0	Negligible Negligible	.05 db .05 db
2249-1	Main Auxiliary	⅞ BNC	2170–2320 30	1.1 : 1.0 1.1 : 1.0	Negligible Negligible	.05 db .05 db
2249-2	Main Auxiliary	Type N BNC	2150–2350 30	1.15 : 1.0 1.1 : 1.0	Negligible Negligible	.05 db .05 db
2250	Main Auxiliary	⅞ ⅞	215–260 215–260	1.1 : 1.0 1.25 : 1.0	Negligible Negligible	.05 db .05 db

DICO
DIAMOND
ANTENNA & MICROWAVE
CORPORATION
River Street • Winchester, Mass.

Vogler received early training in Germany in milit communications. Before coming to the United State 1950, he set up a laboratory for a ceramics firm and work in ultrasonics.

Shortly after he joined Frequency Standards' par machining company, Vogler was assigned full time FS because of his knowledge and related previous perience. He was appointed chief engineer in 1957.

A night school graduate, Vogler holds his BS physics and is a member of the IRE.

Sales Manager Harry Dolan forecasts a steady rat company growth to match the expanding requirem of the microwave industry during the present decade. "The bulk of our customers are prime co tractors," Dolan reports, "but we ourselves are seek prime government contracts for systems which we qualified to develop and produce based on our mic wave experience."

Dolan joined Frequency Standards in 1956 as sistant Sales Manager. He was appointed to his pre post in July, 1959. His responsibilities include ove commercial planning and administration, marke field sales management, advertising and sales promoti

Before coming to FS, Dolan was employed by Ti water Oil Company in dealer sales. He holds a BS gree and is a member of the Armed Forces Communi tions and Electronics Association and the Electronic dustries Association.

At FS's helm, General Manager Slack, appointed Harvard Industries, brings to his job a broad ba ground of management and technical accomplishme Before joining Harvard Industries, Slack was Assist Secretary-Treasurer of National Electric Products With the same company, he had also been Director Organization and Planning and Assistant to the V President-Sales. Earlier, Slack was an Aeronautical search Scientist working on supersonic heat trans problems for the National Advisory Committee Aeronautics. He is the author of several technical pap on heat transfer problems of supersonic flight. Sla holds his BS and MS in mechanical engineering and MS in business administration.

Eye On the Future

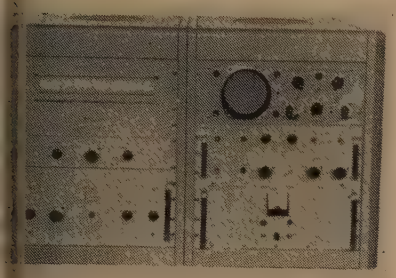
Objective of the new Frequency Standards mana ment is to achieve a more efficient balance betwe prototype work and production. According to E Slack, "We stress quality, service, *and* the capacity produce in quantity. Currently we're on the way tow rounding out our product line to include all the co ponents for microwave r-f front-end systems. La we plan to offer packaged r-f sub-systems which w spare the customer from having to fit separate com nents together himself. At the same time we will c tinue to do certain types of specialized sub-contr manufacturing."

Coupling of dynamic new management with F quency Standards' traditional know-how and qua of workmanship has already brought to the indus an advanced state of the art which promises to ext microwave frontiers to their ultimate limits.

EW PRODUCTS

NEW COMPUTER

electronic analog computer especially ned to solve Fourier integrals has been nced by Scientific-Atlanta, Georgia facturer of microwave instrumentation. own as the Model CF-1, the new in- ent can be used to determine the far of aperture antennas from the dis- ion of the field in the aperture, the elds of arrays from the magnitude and of the currents in the elements, the ency spectra of voltage pulses, and physical problems involving Fourier orms and their inverse transforms finite limits.



operation, amplitude and phase in- unctions are plotted on graph paper resentation to the computer. These ions are taken off the graph with a electric reader, passed through a pulse on to voltage converter and then to priate computing circuitry. egration can be observed on a dc os- cope for interpretation or visual read- Final recording uses Scientific-Atlanta na pattern recording equipment. Typ- . a main lobe and four side lobes e computed and recorded in 15 min-

ce of the 325 pound 46″ wide, 25″ and 22″ deep unit is $9,000 fob ta, Georgia.

cle Reader Service Card 119

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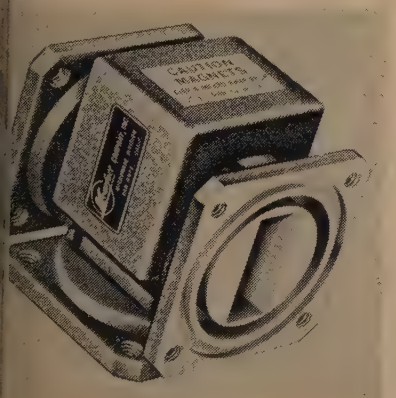
NEW HIGH POWER CIRCULATOR TEE

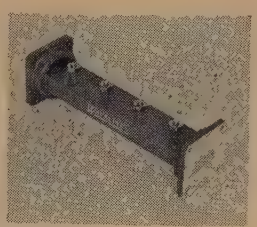
new high power circulator tee with isolation and low insertion loss has developed by Kearfott Company, Inc., owave Division, Van Nuys, California. e Model 380864-1A Circulator Tee is

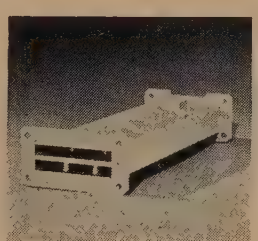


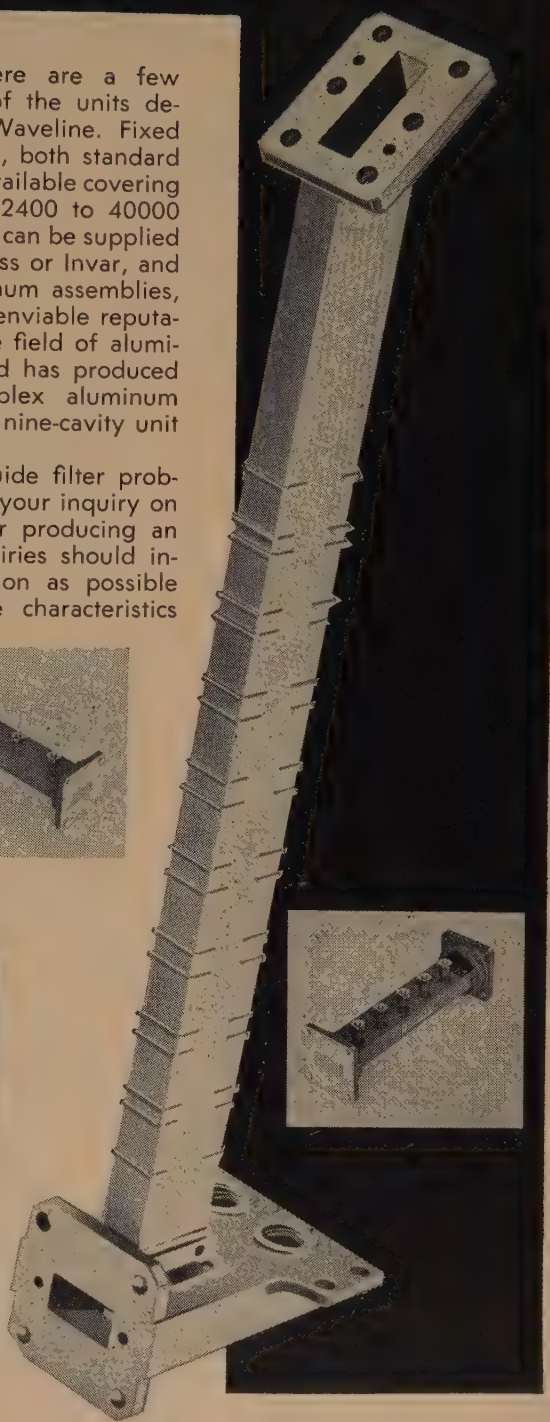
WAVEGUIDE FILTERS

The filters shown here are a few representative samples of the units designed and produced at Waveline. Fixed tuned or tunable designs, both standard or custom designed are available covering the frequency range of 2400 to 40000 Mc/sec. Filter assemblies can be supplied in either silver-plated brass or Invar, and in aluminum. For aluminum assemblies, Waveline has gained an enviable reputation for leadership in the field of aluminum flux-dip brazing and has produced in quantity many complex aluminum filter designs such as the nine-cavity unit shown at the right.

If you have a waveguide filter problem, we would welcome your inquiry on designing a prototype or producing an established design. Inquiries should include as much information as possible concerning the response characteristics desired.







A four page Waveguide Filter brochure describing some standard designs in detail is available on request.

WAVELINE INC.

CALDWELL, NEW JERSEY

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NEW!

S-Band *System-Tested* MICROWAVE COMPONENTS

Engineered to meet complete Military Missile Specifications

S-BAND PULSE OSCILLATOR

- Minimum 1.5 KW Peak Power Output at .001 duty cycle; 1 μsec pulsewidth 1000 pps
- 300 MC Tuning Range
- Operating Conditions: 3000V at 2.5 amp peak (nominal)

S-BAND CW OSCILLATOR

- Minimum 50 mw Power Output 100 mw at lower frequencies
- Exceeds 400 MC Tuning Range
- Operating Conditions: 125V-250V at approx. 20-35 ma depending on plate voltage.

Both oscillators are lightweight (only 20 oz.) with integrated mountings. Both use 6442 triode tube. Heater 6.3V AC or DC.

- Mixer and Diplexer (non-tunable) operate as an integral part of the Filter
- Unit features minimum Insertion Loss, Rejection Bandwidth and Input VSWR.
- Tuning Range: exceeds 300 MC

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Circle Reader Service Card 46

a high power device of relatively small size. Building high power capability into the new Kearfott Tee while reducing size and weight makes the unit particularly useful in missile and space vehicle applications, transponders, beacons, and other airborne radar systems.

The unit's characteristics are as follows: Frequency range: 9.0 to 9.16 kmc; isolation: 16 db minimum; insertion loss: antenna-to-receiver, .2 db maximum; transmitter-to-antenna, .4 db maximum; input VSWR: 1.15 maximum; peak power: 50 kw; average power: 50 watts.

Circle Reader Service Card 120

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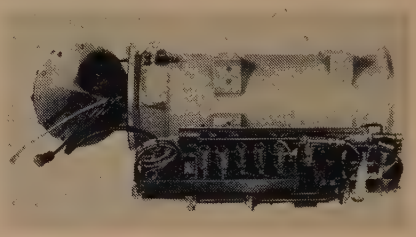
PARAMETRIC AMPLIFIER RECEIVING SYSTEM

The A I L Type 7658 Parametric Amplifier Receiving System, designed and manufactured by Airborne Instruments Laboratory of Mineola, N.Y., is a complete re-



ceiving system with r-f front end and IF output. Overall system noise figures from 1.9 to 2.9 db have been achieved and are dependent upon the diode used.

The Type 7658 can be housed in a compact metal container as shown, while other housings are also obtainable. Two power supplies — one for the IF amplifier and the other for the klystron pump — and a local oscillator are mounted external to the unit shown.

Complete specifications are as follows: Frequency: 960 ± 75 mc; noise figure 1.9 to 2.9 db; pump frequency: 9840 mc; gain of reactive stage: 18 db; bandwidth 20 mc; IF output: 30 mc; IF bandwidth 2 mc; price: $9850.

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LITERATURE . . .

VOLTAGE-TUNABLE MAGNETRON BOOKLET

Bulletin PT-1, 26 pages, provides information on four new S-band package voltage-tunable magnetrons developed by General Electric's Power Tube Department.

The manual includes data on the design, typical applications, operation, and production of VTM's.

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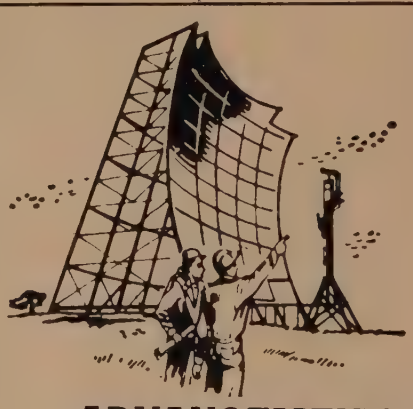

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SOLID STATE CIRCUITS CONFERENCE PROGRAM

1960 International Solid-State Circuits Conference at the University of Pennsylvania — Hotel Sheraton, Philadelphia, February 10, 11, 12, 1960, will feature eight sessions devoted to broad advances in the field of solid-state device ications and circuits. Forty-three papers will be offered covering new magnetic and semiconductor devices and uits for digital storage and logic. Also presented will be a number of survey reports on tunnel diodes, thin magnetic and microwave properties of semiconductors.

mal discussion sessions, conducted by leaders in the solid-state field, will be held on Wednesday and Thursday ngs to provide registrants an opportunity to discuss tunnel diodes and their applications, storage techniques, relia-, noise theory, logic circuits, microelectronics, parametric applications and energy conversion.

registrant will receive a 100 page letterpress conference-report book featuring digests of every paper, supplemented ver 300 illustrations. Post-conference copies of the report will be available at $5.00 each.

further information contact: Lewis Winner, 152 West 42nd Street, New York 36, N.Y., BRyant 9-3125.

PROGRAM

nesday Morning, February 10, 1960

ION I

plications of Tunnel Diodes
ine Auditorium 9:00 - 11:45 a.m.
man: T. R. Finch, Bell Telephone os.
Esaki Diodes: *A Survey* — G. C. cey, Bell Telephone Labs.
Tunnel Diodes and Their Use as ulti-Junction Circuit Elements — J. J. man, G.E. Research Laboratory.
The Tunnel Diode as a Logic Element M. H. Lewin, A. G. Samusenko and W. Lo, RCA.
Circuit Principles for Applications of aki Diodes at Microwave Frequencies M. E. Hines, Bell Telephone Labs.
Tunnel Diode Radio Frequency Am- fier — E. Miller, H. B. Yin and J. ultz, RCA.
Esaki Diode Logic Circuits (To be esented in Session E7) — G. W. Neff, A. Butler and D. L. Critchlow, IBM.
al Opening of Conference: 1:45 - 45 P.M. — Irvine Auditorium
ductory Comments — *Arthur P. Stern,* E. Electronics Lab., Chairman of Con- ence
oming Remarks — *G. P. Harnwell,* esident, University of Pennsylvania
ed Addresses — *C. Guy Suits,* Vice- esident and Director of Research, G.E. "The Impact of Solid-State Re- search On U.S. Industry and Tech- nology"
. J. O. Strutt, Chairman, Electrical En- neering Department, Swiss Federal In- tute of Technology
"Solid-State Circuits Research in Europe"

nesday Afternoon, February 10, 1960

Dudley Buck Memorial Session

SION II

hin Magnetic Films for Logic and emory
vine Auditorium 2:45 - 5:15 p.m.
hairman: E. W. Fletcher, MIT
Thin Magnetic Films: *A Survey* — A. . Pohm, Iowa State College
High-Speed Magnetic-Film Logic — W. E. Proebster, IBM, Zurich, Switzerland
2.3: A Thin Magnetic-Film Shift Register — K. D. Broadbent and F. J. McClung, Jr., Hughes Research Labs.
2.4: An Evaporated-Film Cryotron Circuit — C. R. Smallman, M. L. Cohen, A. E. Slade and J. L. Miles, Arthur D. Little, Inc.

Wednesday Evening, February 10, 1960

8:00 p.m.: Informal Discussion Sessions Sheraton Hotel

E.1: Tunnel Diode Characterization — Moderator, G. C. Dacey, Bell Telephone Labs.
Panel Members: D. E. Thomas, BTL; J. J. Tiemann, G.E.; S. L. Miller, IBM; H. Somers, RCA.

E.2: Thin Films for Memory — Moderator, A. V. Pohm, Iowa State College
Panel Members: J. I. Raffel, MIT: S. M. Rubens, RR; D. A. Meier, NCR; R. A. Tracy, Burroughs; D. H. Looney, BTL; I. W. Wolf, GE.

E.3: Reliability Considerations — Moderator, W. D. Rowe, Westinghouse
Panel Members: J. J. Scanlon, BTL; G. T. Ross, RCA; K. Davidson, Texas Inst.; C. J. Thorton, Lansdale Tube Co.; G. E. Cunnihan, Stromberg-Carlson.

E.4: Noise Theory — Moderator, J. G. Linvill, Stanford University
Panel Members: R. P. Rafuse (Author of paper 8.6) MIT; W. E. Dahlke, Telefunken; R. B. Adler, MIT; D. A. Linden, Stanford Univ.; P. Penfield, Jr., MIT; C. S. Kim, GE.

E.5: Energy Conversion — Moderator, S. J. Angello, Westinghouse
Panel Members: H. Reiner, Standard Elektrik; S. R. Hoh, ITT; P. S. Castro, Lockheed; D. A. Paynter, GE; R. P. Putkovich, Westinghouse.

E.6: Magnetic Logic — Moderator, D. C. Engelbart, Stanford Res. Inst.
Panel Members: U. F. Gianola, BTL; E. P. Stabler, GE; A. J. Meyerhoff, Burroughs; H. P. Wolff, IBM; W. E. Proebster, IBM; T. H. Bonn, RR Univac; D. Muir, NCR; H. D. Crane, Stanford Res. Inst.

Thursday Morning, February 11, 1960

SESSION III

Digital Logic
Irvine Auditorium
9:00 a.m. - 12:00 noon

Chairman: R. A. Henle, IBM
3.1: Improvements in Current Switching — F. K. Buelow, IBM
3.2: Tunnel-Diode Digital Circuitry—W. F. Chow, GE Electronics Lab.
3.3: A Modulation-Demodulation Scheme for Ultra High-Speed Computing and Wide-Band Amplification — W. Eckhardt and F. Sterzer, RCA
3.4: Adaptive Logic — R. J. Domenico and R. A. Henle, IBM
3.5: Design of a Solid-State Neuron Circuit for Use in Self-Organizing Systems — C. L. Coates and E. A. Fisch, GE Electronics Lab
3.6: Fast Logic Using Transistor Current-Routing Techniques (To be presented in Session E12) — D. B. Jarvis, L. P. Morgan and J. A. Weaver, Mullard Research Laboratories, Salsford, England

Thursday Morning, February 11, 1960

SESSION IV

Applications of New Devices
University Museum
9:00 a.m. - 12:00 noon

Chairman: H. W. Katz, GE Electronics Lab.
4.1: A Broad-Band, Fast-Acting, Ferrite Switch — D. E. Allen and N. G. Sakiotis, Motorola, Inc.
4.2: A Solid-State Modulator for Millimeter Waves — E. T. Harkless and R. Vincent, Bell Telephone Labs.
4.3: Low-Noise Tunnel-Diode Down-Converter Having Conversion Gain — K. K. N. Chang, W. Y. Pan, H. B. Yin, G. H. Heilmeier, D. J. Carlson and H. J. Prager, RCA
4.4: Photorectifier Based on a Combination of a Photoconductor and an Electret — J. G. van Santen and G. Diemer, N. V. Philips Gloeilampenfabrieken, Eindhoven, The Netherlands
4.5: A New High-Speed Effect in Solid-State Diodes—A. F. Boff, R. Shen, Hewlett-Packard Co., and J. L. Moll, Stanford University

Thursday Afternoon, February 11, 1960

SESSION V

Information Storage Techniques
Irvine Auditorium 1:30 - 5:00 p.m.

Chairman: A. W. Lo, RCA

5.1: The Tunnel Diode as a Memory Element — J. C. Miller, K. Li and A. W. Lo, RCA

5.2: Sub-Microsecond Core Memories Using Multiple Coincidence — H. P. Schlaeppi and I.P.V. Carter, IBM, Zurich, Switzerland

5.3: Fluxlok — A Non Destructive High-Speed Memory Technique Using Standard Ferrite Cores — R. M. Tillman, Burroughs Corp.

5.4: Low Coercive-Force Ferrite Ring Cores for a Fast Non-Destructively Read Store — G. H. Perry and S. J. Widdows, Royal Radar Establishment, Great Malvern, England

5.5: Memory for a 40-Megacycle Deltic Correlator — W. Peil and J. Hesler, GE Electronics Lab.

5.6: Partial Switching, Non-Destructive Read-Out Storage Systems (To be presented in Session E8) — W. L. Shevel, Jr., and O. A. Gutwin, IBM

Thursday Afternoon, February 11, 1960

SESSION VI

Linear Amplification and Generation
University Museum 1:30 - 5:00 p.m.

Chairman: F. H. Blecher, Bell Telephone Labs.

6.1: Circuit Applications of a Coaxially Encapsulated Microwave Transistor — V. R. Saari, C. A. Bittmann and R. E. Davis, Bell Telephone Labs.

6.2: Tunnel Diode Amplifiers with Unlimited Gain-Bandwidth Products — E. W. Sard, Airborne Instruments Lab.

6.3: Superconductive Devices and Electrical Measurements at Low Temperatures —I. M. Templeton, National Research Council, Ottawa, Canada

6.4: Solid-State Sampled-Data Bandpass Filters — L. E. Franks and F. J. Witt, Bell Telephone Labs.

6.5: Analysis of Transistor Class C Oscillators — J. A. Narud, Harvard University

Thursday Evening, February 11, 1960

8:00 p.m.: Informal Discussion Sessions
Sheraton Hotel

E.7: Tunnel Diode Applications — Moderator, A. W. Lo, RCA
Panel Members: G. W. Neff, IBM (Co-author of paper 1.6); M. E. Hines, BTL; W. F. Chow, GE; E. W. Sard, AIL; K. K. N. Chang, RCA.

E.8: Storage Techniques — Moderator, J. A. Rajchman, RCA
Panel Members: W. L. Shevel, IBM (Co-author of paper 5.7); R. M. Tillman, Burroughs; W. Peil, GE; G. H. Perry, Royal Radar Est.; H. P. Schlaeppi, IBM; J. C. Miller, RCA; J. E. Mack, BTL.

E.9: Microelectronics — Moderator, G. Sziklai, Westinghouse Elec. Corp.
Panel Members: I. N. Ross, BTL; D. C. Engelbart, Stanford Res. Inst.; P. B. Myers, Motorola; W. Adcock, Texas Instr.; H. W. Henkels, Westinghouse; R. Norman, Fairchild; A. McWhorter, MIT; I. A. Lesk, GE.

E.10: Parametric Applications — Moderator, B. Salzberg, Airborne Instr. Lab.
Panel Members: R. S. Engelbrecht, BTL; H. Hsu, GE; L. Negaard, RCA; A. Berk, Hughes; K. E. Schreiner, IBM; Robert Adler, Zenith.

E.11: High-Frequency Amplification and Generation — Moderator, J. B. Angell, Philco
Panel Members: V. H. Grinich, Fairchild; J. M. Early, BTL; F. F. Blecher, BTL; C. H. Knowles, Motorola; L. D. Wechsler, GE; R. L. Pritchard, Texas Instr.

E.12: Semiconductor Logic — Moderator, W. B. Cagle, Bell Telephone Labs.
Panel Members: L. P. Morgan, Mullard Res. Labs. (Co-author of paper 3.6); E. G. Seymour, GE; F. K. Buelow, IBM; M. H. Lewin, RCA; R. Schauer, Iowa State College; J. Lynch, Burroughs.

Friday Morning, February 12, 1960

SESSION VII

Microelectronic Considerations
Irvine Auditorium
9:00 a.m. - 12:00 noon

Chairman: J. R. Nall, Fairchild Semiconductor Corp.

7.1: Microelectronics and the Art of Silicon — D. C. Engelbart, Stanford Research Institute

7.2: Speed, Power, and Component Density in Multielement High-Speed Logic Systems — J. M. Early, Bell Telephone Labs.

7.2: Concept of Molecular Engineering — H. W. Henkels, Westinghouse Electric Corp.

7.4: Solid-State Micrologic Elements — A. Haas, J. T. Last and R. H. Norman, Fairchild Semiconductor Corp.

7.5: Semiconductor Inductance Diode — Y. Nishizawa and Y. Watanabe, Tohoku University, Sendai, Japan.

Friday Afternoon, February 12, 1960

SESSION VIII

Parametric Circuit Techniques
Irvine Auditorium 1:30 - 4:30 p.m.

Chairman: H. Heffner, Stanford University

8.1: Microwave Properties of Semiconductors: *A Survey*—H. Kroemer, Varian Associates

8.2: Low-Frequency Reactance Amplifier — J. R. Biard, Texas Instruments, Inc.

8.3: A Passive Parametric Limiter — A. Wolf and J. E. Pippin, Sperry Microwave Electronics Co.

8.4: Backward Traveling Wave Parametric Amplifier — Hsiung Hsu, GE Electronics Lab.

8.5: An Analysis of Sub-Harmonic Pumping of Parametric Amplifiers — K. Mortenson, GE Research Lab.

8.6: Measurement of Absolute Noise Performance of Parametric Amplifiers (to be presented in Session E4) — R. Rafuse, MIT

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ured in the catalog are 50 ohm rigid coaxial transmission line in 7/8", 1/8", 6 1/8" sizes; 50 ohm rigid alum- coaxial transmission line in 1 5/8", 1/8" sizes; and a special rigid alum- coaxial transmission line using the odelin Spir-O-lok connector, Prode- nique development that enables con- s to be made without brazing and exceptionally rapid field assembly. pecial line is available in 1 5/8", 3 1/8", 6 1/8" and 9" sizes. Accessories and ing hardware for all lines are illus- and described.

ensions are given for the Spir-O-lok ors and EIA connectors in all sizes. dition to the above, the catalog s six pages of engineering data and hance curves. Also listed are typical ation systems installations.

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latest issue of "PRD Reports," Vol. 3, entitled "Dry Calorimetric Power " discusses a more accurate method measurement of microwave power er frequencies.

hored jointly by Messrs. Michael J. , Leo A. Nadler, and Stanley J. ard, of the staff of the Brooklyn, rm, the report describes power meter entation for dry calorimeters which readout time from about 10 min- 45 seconds and eliminates calibra- arts previously needed to correct for level and ambient temperature.

ry Calorimetric Power Meter com- coaxial and waveguide calorimeters instrumentation housed in a single e is discussed in detail.

ies of "PRD Report" Vol. 6, No. offered free.

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al Textile Corporation, a division neral Cable Corporation, Roselle, Jersey, is making available its Data File.

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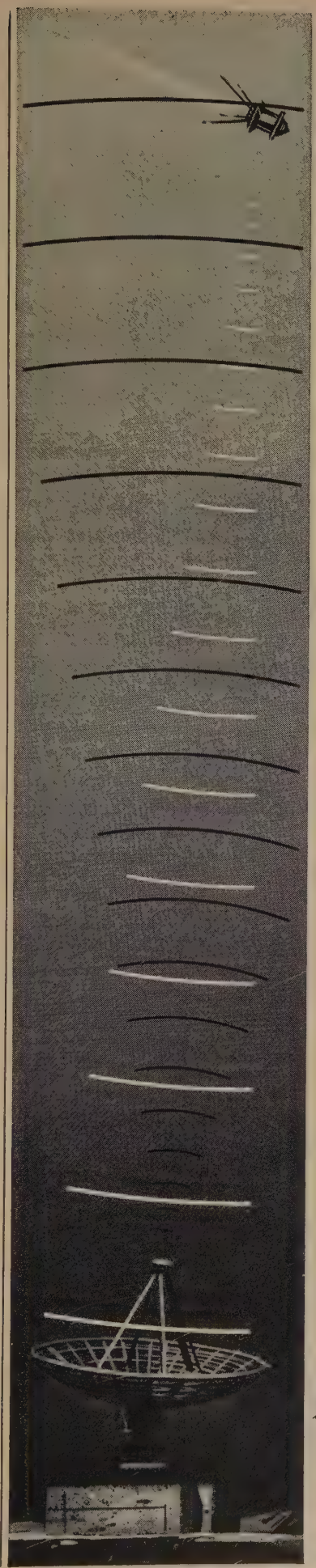

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Circuit Shorts . . .

Reflecting on the 1959 NEREM show, it is consensus of opinion that this has becom one of the more important shows of the year, an it will be interesting to watch its progress in th years to come.

Coincidental with the NEREM show was the r turn of Donald Sinclair, Vice-President an Chief Engineer of General Radio Co. from th recent Colloquium on Microwave Communic tions at Budapest. During an informal confere at the Hotel Kenmore, Dr. Sinclair described h experiences as the only American guest at th event, and we hope in the near future to have more lengthy paper on conclusions drawn fro these experiences. It was apparent to Dr. Sinclai that Hungary, with an electronics indust started by German and British interests befo the war, is striving to become the chief electroni production center of the Soviet bloc.

Later on came the Eastern Joint Computer Co ference, at Boston's Statler-Hilton, and th too, was a very busy affair. Laboratory for Ele tronics Computer Division introduced their ne storage device, based upon a centuries-old pri ciple of the Bernouilli disc. By the application o this principle, LFE says that the price per bi of stored information can be considerably re duced.

An interesting facet of the symposium pictu turned up when CDB Enterprises, Long land, conducted a display of new product lines t their various clients at Roosevelt Field Decemb 7 and 8, 1959. The showing was unique in that th product display was combined with technic sessions each evening. The sessions were co ducted by Chris Berger, and consisted of ta delivered by engineering officials of the displa ing firms.

Speakers included: Herman Chait, Direct of Research, Cascade Research Division, Mon gram Precision Industries; Harry J. Andrew Sales Manager, Fenwal Electronics Co.; Jo Dodenhoff, Chief Engineer, Glass-Tite Industri Inc.; Reverend Brother Thomas G. Bullen, He Science and Mathematics Dept., Iona Colleg Dr. Michael J. DeToro, Director, Research Development, Polytechnic Research & Develo ment Co.; Sherman Rinkle, Director of Engine ing, Polytechnic Research & Development C Louis W. Roberts, Staff Physicist and Direct Microwave Electronic Tube Co.; Robert S. G don, Director of Research, and Edgar Gotth Foundry Superintendent, Gorham Manufacturi Co. Electronics Div.

Morris Robison, President of Antlab, Inc. w also scheduled to speak, but illness prevented attendance.

There was also a panel discussion on mic wave ferrite devices, conducted by Mr. Chait —J. W. H

CORRECTION

pographical error in "This Micro- Business" column in the December of *the microwave journal* makes Mr. William Bazzy's article entitled, ous Sixties! — or Decade of Prob- confusing.

graph 8 on page 81 should read: ebruary Charles Creaser of D. S. y noted the "Large Antenna" market oximately $25 million. In May, Paul n of ITE estimated the "Small An- market at about $250 million. *Dave stated in February that waveguides mbing sub-systems would run close 0 million.* The Bomac people, in rofile of *November 1958* felt that crowave tube market should total illion for 1959. Information gleaned other industry sources corroborate mounts. A release from the Business fense Services Administration (noted e 52) gives the latest analysis of the arket.

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PAPERS

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Philco Corporation	15,
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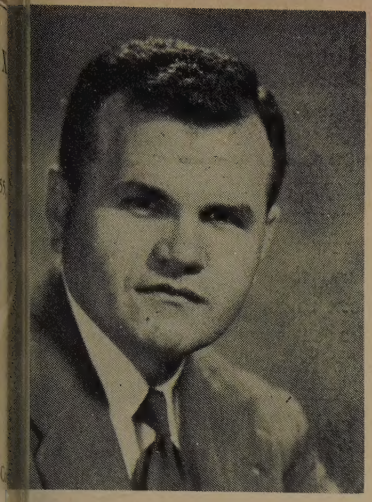

REPORT ON INTERNATIONAL CONFERENCE FOR WAVEGUIDE STANDARDIZATION

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the microwave journal

The first practical use of waveguide in the electronic industry occurred just twenty years ago and today the ufacture of waveguide and microwave components has grown to a $90,000,000 annual business. (This, of se, excludes the overall systems value and just takes into account the test equipment and components which lve waveguide and waveguide flanges.) With any program of engineering and production effort, standard- on is required to avoid duplication and simplify systems design and manufacturing.

angular Waveguide

he ideal form factors for rectangular waveguide been known, on a theoretical basis, for many years. use of waveguides, on a practical basis, dates, how- only from World War II. Waveguide was given iderable impetus by the dictates of radar applica- for microwaves during the war. Unfortunately, the ngular tubes, which were most readily available at time, were architectural metal tubes whose dimen- were based on esthetic considerations rather than electrical performance; some of the earliest types of guides used were 1" x ½" tubing with a .900 x ID; also, some of the ticket tubes which were used neumatic delivery systems were used in the S-band on early in the war.

s a result, a collection of waveguide, based on nom- outside dimensions were in use for military applica- and it became apparent to the Electronic Indus- Association (then the RMA — Radio Manufac- 's Association, subsequently REMA and RETMA) a standard series of waveguide for industry-wide ication was required.

he military series of waveguides, or more collo- lly called the standard series of waveguides, formed basis of a continuous series of waveguides that fit tary applications covering from 1000 megacycles on o 40,000 megacycles. The EIA committee on wave- es decided that the military series, although it did r the frequency range, did not provide sufficient lap for certain systems applications and a second s (Series B) was added to the series to provide a plete series, — the Series B, of course, having an 2:1 aspect ratio. This compilation of waveguide ension has been published as EIA Standard TR-108. n England, a series based on the use of 1" x ½" ID popular acceptance and, of course, being a 2:1 as- ratio, had nearly ideal performance characteristics he X-band region. Also, being somewhat larger than our X-band, fitted the operating frequency range somewhat better. (Bell Telephone Labs, early in the war, went to the so-called large X which is now one of the Series B waveguides.) The French came up with a metric series of waveguide which has been used by some European countries.

It became apparent to the International Electrotechnical Commission that waveguide standards for international application were long overdue. As a result, the Committee on Transmission Lines, 40-2 of the IEC, added to its agenda the formation of waveguide standards back in 1950. Considerable discussions were held on the various merits of all the waveguide schemes, but the total weight of the original war time effort and subsequent military development which came along with it in the American series finally swung the international group over to adopting, for rectangular waveguide use, the American series of rectangular waveguides.

At the recent IEC meetings in Ulm, Germany, which I had the good fortune to attend, this philosophy was confirmed with certain important considerations. The standard tolerance on waveguide was decided to be held to one part in 500 throughout the series, which meant that waveguides of the American standards larger than WR 284 have, by American Standards, tighter dimensional tolerances than the international standard. However, the reverse is true below WR 284 and the smaller American waveguide sizes have lower tolerances than the international standard. As is generally acknowledged throughout the microwave industry, the present waveguide standard tolerances are lower than is desirable and it is generally felt that a tightening of the basic waveguide tube standard is required, to insure that the American standards exceed or equal the international standards.

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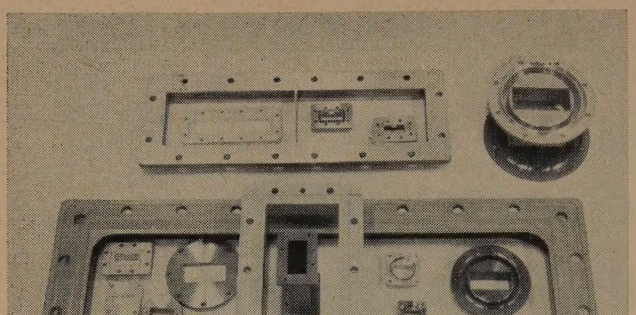
*Formerly with Airtron Division, Litton Industries.



Flat Waveguide

Considerable interest has also been shown in the European countries for flat waveguides — waveguides having an aspect ratio of considerably less than 2:1 and a whole series of these flat waveguides is also included in the international standard.

Circular Waveguide

The EIA pioneered a circular waveguide standard which is now RS-200. The IEC has essentially adopted this standard, but has provided for a greater number of intermediate sizes to fit a wide variety of applications and to allow somewhat smaller operating ranges for circular waveguides for higher order mode operation.

International Waveguide Standard

A draft of the waveguide standard was agreed upon for circulation to all countries under the six-month's rule. This is close to being accepted as an international standard, waiting only on review by all of the member countries and action by the committee on comments and corrections received. Another issue of *the microwave journal* will publish this international standard in detail.

Waveguide Connector Standardization

With the adoption, by the international group of essentially the American series of rectangular waveguides, it was hoped that the American series of rectangular waveguide connector standards would be given serious consideration. Since, as chairman of the EIA TR 21.1.1 Sub-Committe on Waveguide Connector Standardization, I was most familiar with the American standardization program and its history and philosophy, I was asked to attend the meetings in Ulm, Germany.

These meetings were very splendidly run by the IEC; excellent meeting room facilities were provided and, with the German delegation as host, no detail was overlooked in providing for the delegates. In the atmosphere of a medieval German town on the Danube, close to the Schwabischen Alps, we met to go over the waveguide connector standard problems.

The prime problem in waveguide connector standards, now that the rectangular waveguide had been chosen, was the dilemma of the inch (unified threads) screw versus metric hardware. As all scientific men will agree, the metric system is slated for international adoption eventually. However, the inch countries have a vested interest in tools and measuring equipment. With the adoption, some years ago, of the factor that 1″ = 25.4000 — (or out) mm, the inch, by international agreement, is thus tied to the international meter; we are, in essence, using the metric system.

The metric countries, on the other hand, are firmly entrenched with the metric system and, likewise, are unwilling to compromise on an international standard that did not provide for metric screw threads. When one considers the bolt hole clearances and the effects of these clearances on waveguide misalignment in flange designs, it is virtually impossible to arrive at a satisfactory solution based on a single thread standard, or a standard which would provide for either inch or metric threads. If one resorts to using nothing but special nuts and bolts and appropriate clearance holes, several things occur:

1. The designer of compact microwave equipment is severely limited;
2. The supply of hardware becomes a logistic problem.

It was felt that these were untenable situations. As a result of considerable deliberation, it was decided that the basic flange designs which were in common use in the United States would be used to provide a series of choke and cover flanges, miniature contact flanges and pressurizable contact flanges for all of the rigid waveguide sizes with two designations;

—I to indicate inch (unified threads) and clearance holes where appropriate and,

—M to indicate metric hardware.

The hole locations would, in each case, be identical.

As part of the standard, it would be suggested that hardware would be furnished for the appropriate flange and/or waveguide assembly, as required, in order to simplify waveguide coupling.

It was felt that, in the event a metric flange were to face an inch flange in coupling up a microwave system, several choices will be available to the systems designer;

1. Use special hardware, such as convertors or adaptors
2. Drill out the smallest hole to fit the available hardware.

This compromise resulted in the adoption of a microwave flange which would, at a later date, provide for the waveguide connector consistent with the metric system.

A number of waveguide connector problems still require solution:

1. The design of millimeter waveguide connectors,
2. The design of choke and cover flanges for some of the Series B waveguides,
3. The design of circular waveguide connectors.

Our European delegation will be submitting flange designs for the flat waveguides to fit, essentially, European flat waveguides in common usage.

Several new areas for standardization work have appeared at the meetings. One of these was the submission by the American delegates of a series of single and double ridge waveguides covering both a 2. 4:1 and a 3. 6 frequency range. With the adoption of ridged waveguide standards comes the problem of standards suitable for waveguide connectors for such systems and these will be taken up, first here under EIA supervision and then eventually, for international standardization.

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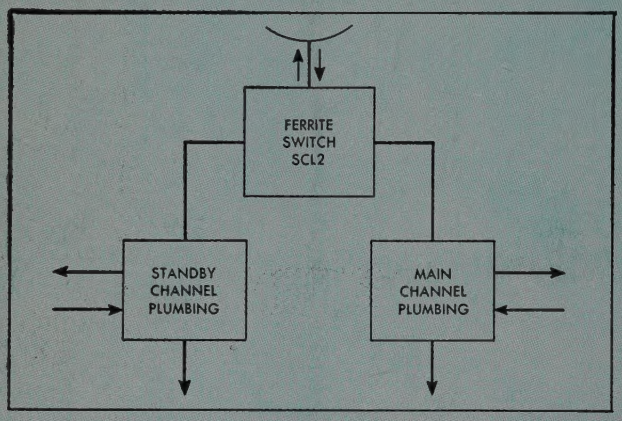
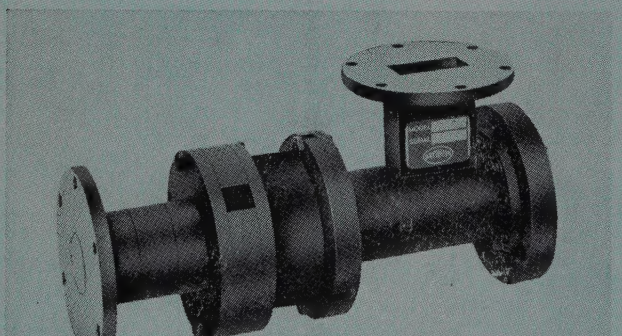
THREE-POSITION FERRITE SWITCH FOR C-BAND



TYPICAL MICROWAVE CIRCUIT in which Raytheon ferrite switch is now being used. Switch has three positions: antenna to main channel; antenna to standby channel; antenna to both channels simultaneously.



FERRITE SWITCH SCL2

FERRITE SWITCH IS ACTIVATED when fault is detected in sensing unit. Receiver fault causes switch to transfer to intermediate position for comparison of main and standby. Normal baseband receiver noise and pilot tone allow switch to complete switchover.

TYPICAL SPECIFICATIONS

	SCL2
Frequency range (mc)	*6,575-6,875*
Isolation, minimum	*20db*
Isolation, maximum	*30db*
Insertion loss, minimum	*0.5db*
Insertion loss, maximum	*0.8db*
Power, average	*10 watts*
Power, peak	*1 kw*
VSWR, minimum	*1.02*
VSWR, maximum	*1.28*
Type of switch	*SPDT reciprocal*
Coil current	*400 ma*
Coil resistance	*60 ohms*
Length	*8 in.*
Waveguide	*RG-50/U**

*Mates with

ADVANCED SWITCHOVER PROTECTION PERMITS MORE RAPID AND FLEXIBLE OPERATION THAN EVER BEFORE

A completely new ferrite switch has just been introduced by Raytheon. The device, which is controlled by a specially designed switchover unit, provides foolproof switchover protection. It has three positions connecting:

1. antenna to main channel
2. antenna to standby channel
3. antenna to both channels simultaneously

In the third position, the received signal is divided equally between the arms feeding the main and standby receivers.

This allows an actual comparison of the two received signals before switching and eliminates the need for complex and unreliable signal injection systems.

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